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MARCH 1941

THE JOURNAL OF THE INSTITUTION OF ELECTRICAL ENGINEERS

ISSUED IN THREE PARTS

PART I. GENERAL (*Monthly*) PART II. POWER ENGINEERING (*Alternate Months*)
PART III. COMMUNICATION ENGINEERING (*Quarterly*)

PART I. GENERAL

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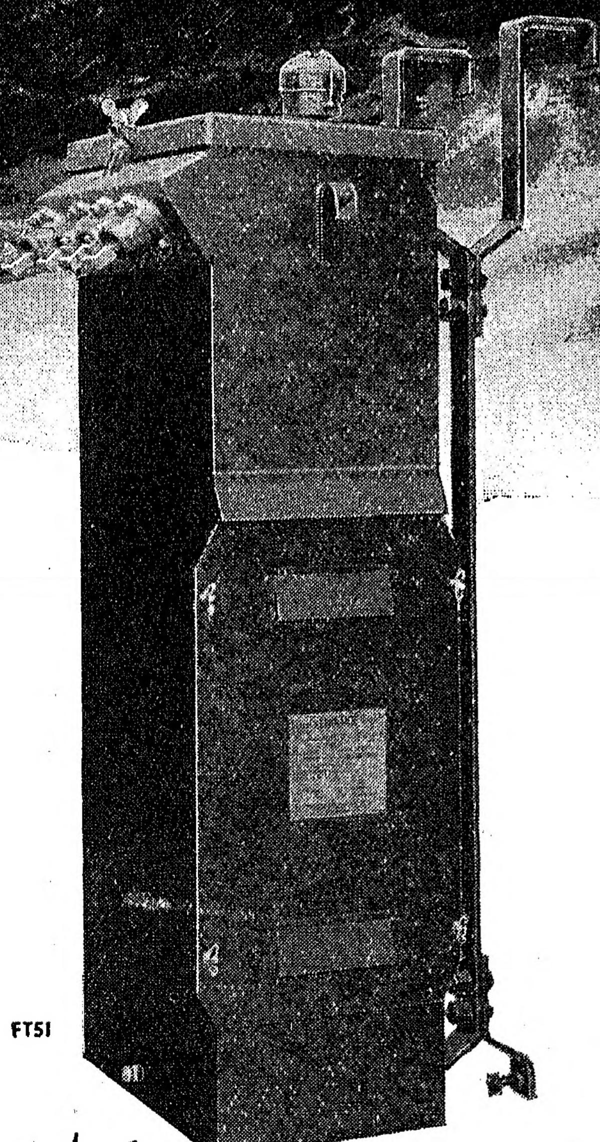

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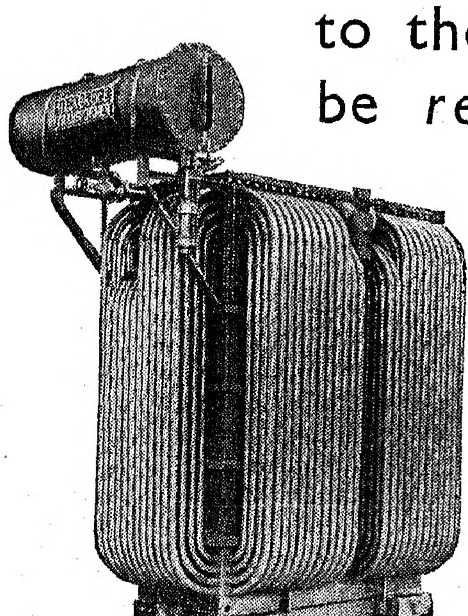

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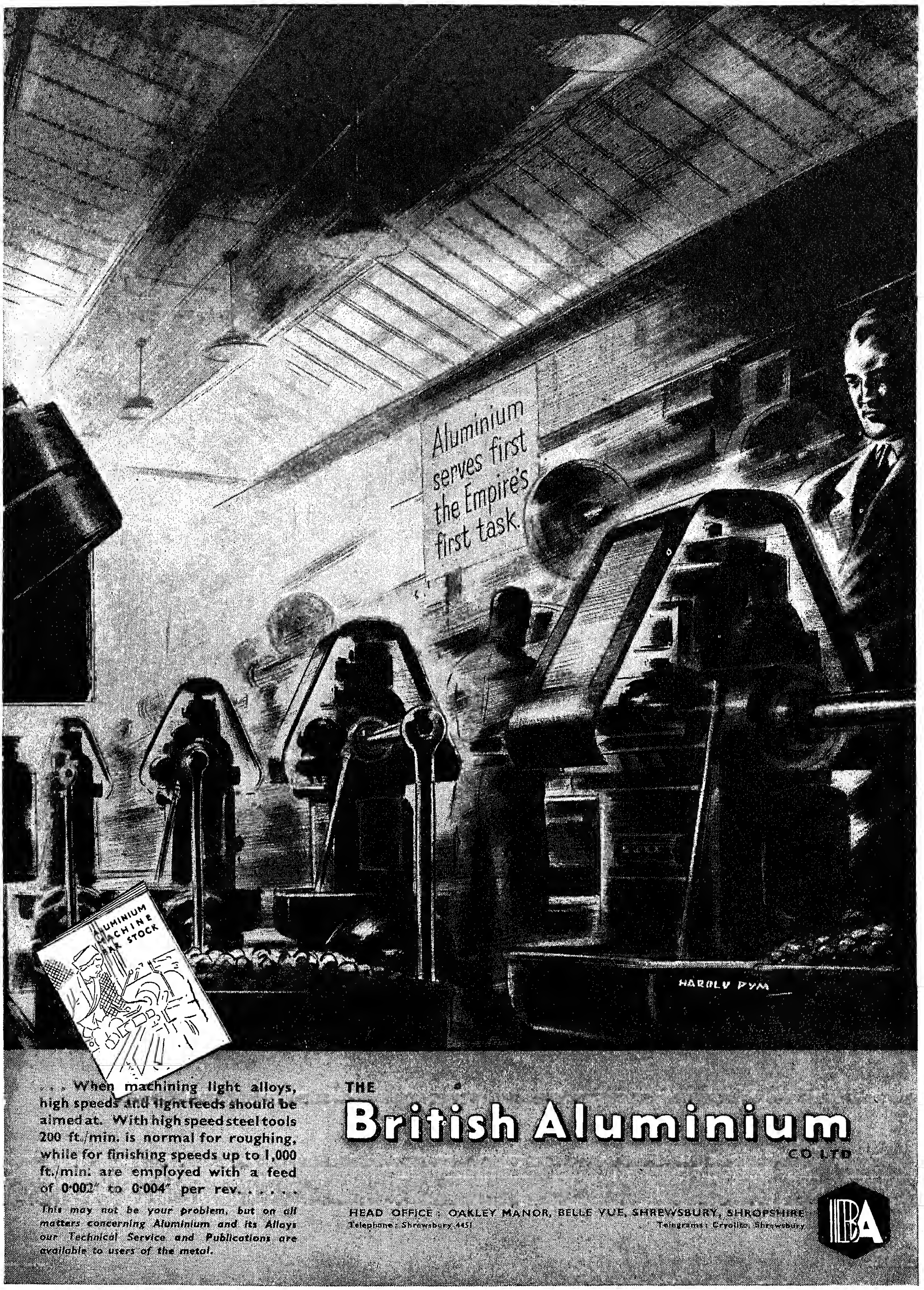
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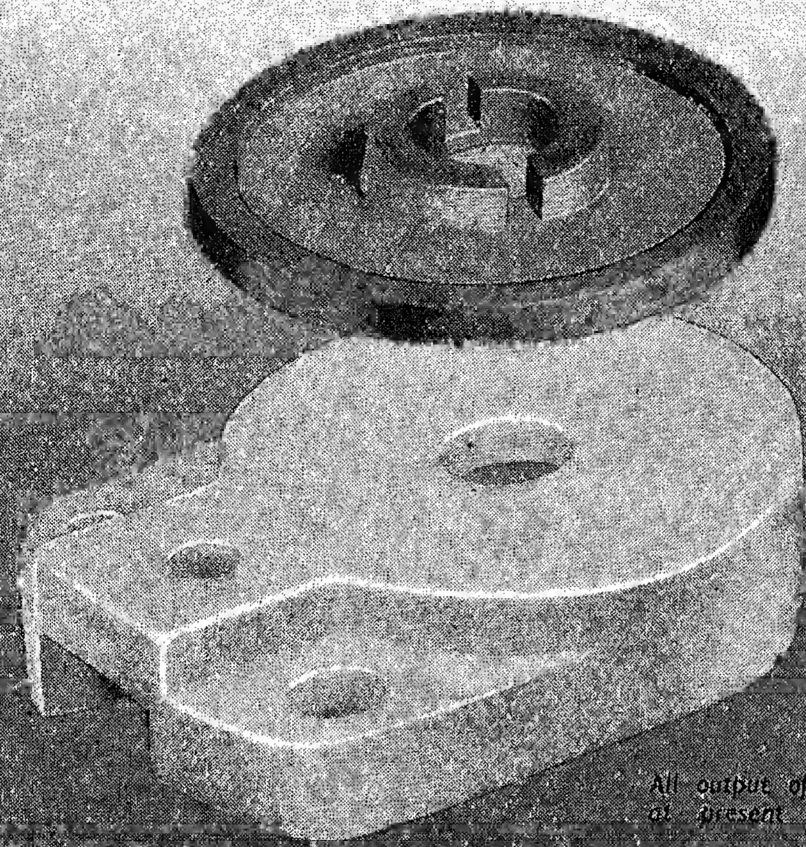

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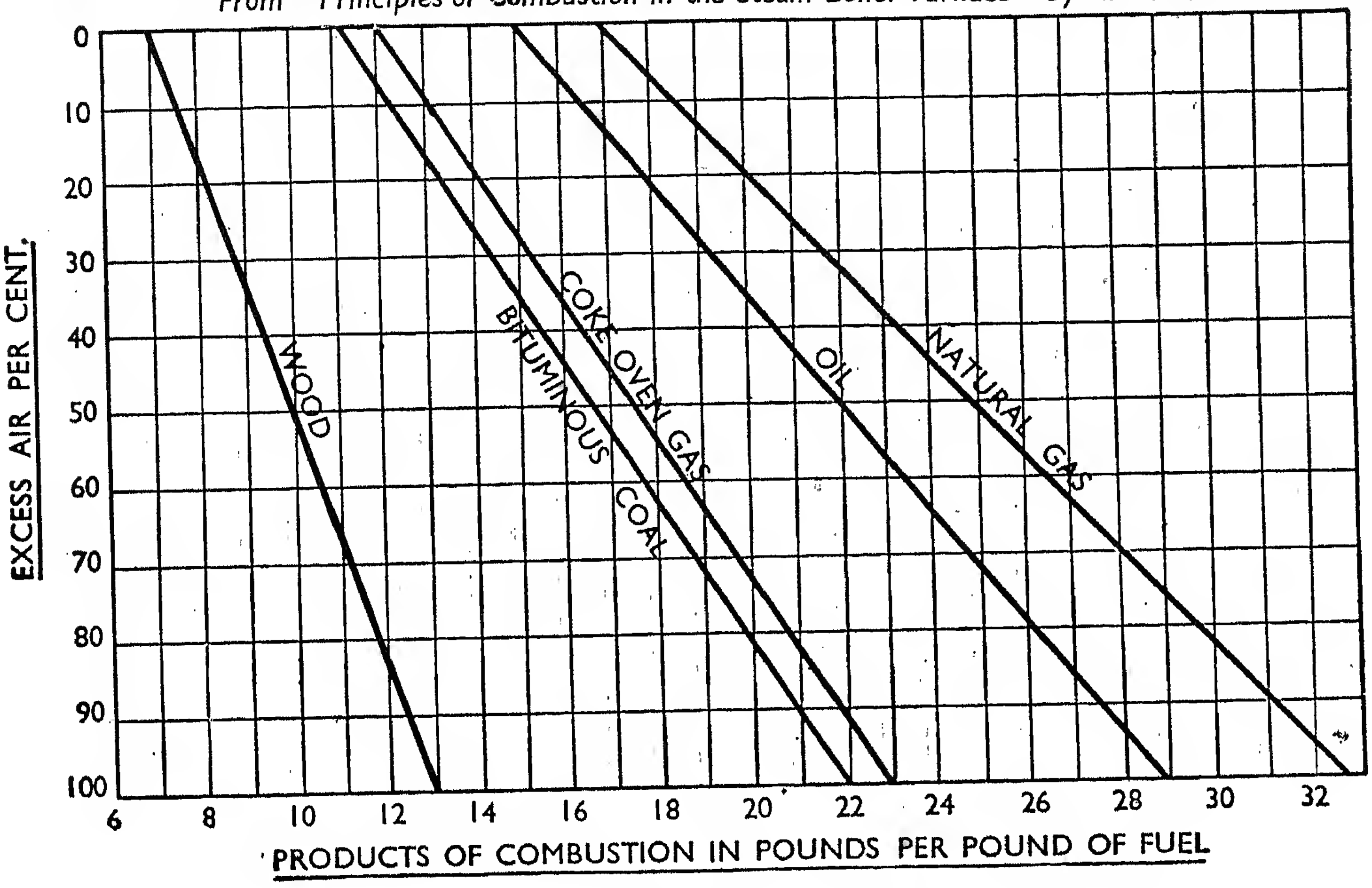
What does CO_2 mean?

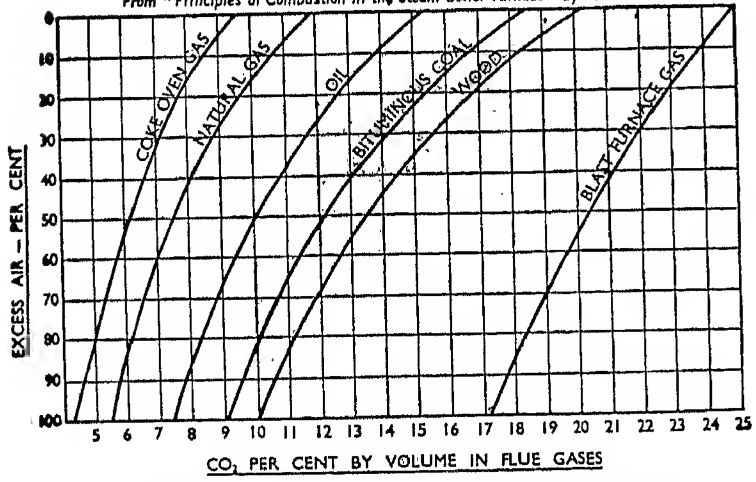
Relation Between Excess Air and Products of Combustion

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



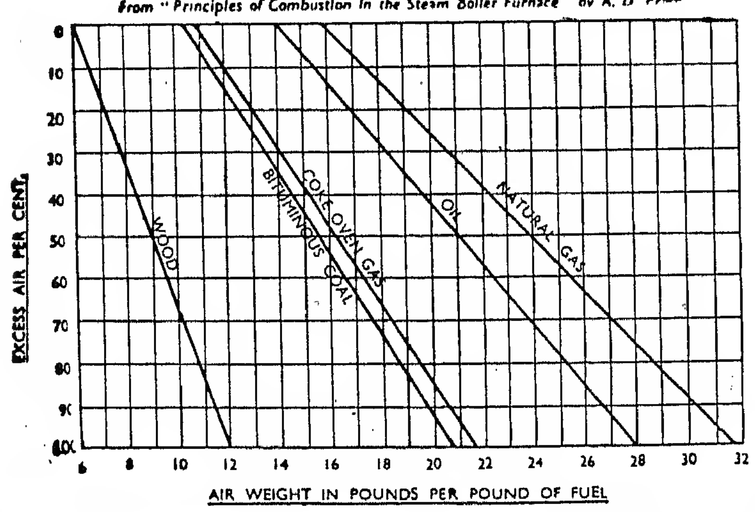
Relation Between Excess Air and CO_2

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



Relation Between Excess Air and Air Weight

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



FROM the above chart it will be seen that when burning 1 lb. of coal, an increase from 20% to 100% excess air means that the weight of the products of combustion is increased by approximately 8½ lb.

Our previous advertisement showed that this increase in excess air involved an increase in the weight of air for combustion by the same amount. Thus the forced draught and the induced draught fans together must handle approximately 17 lb. more air and products of combustion than that necessary for efficient combustion.

In the case of a boiler for 175,000 lb. of steam per hour, with 20% excess air the fan motors would be rated at 196 h.p., which would be increased at 100% excess air to 875 h.p. thus involving an increase in electrical input to the motor terminals of 570 KW. Assuming 20 hours per day and 300 days per year, at ½d. per KWH this unnecessary expenditure in fan power amounts to £7,130 per annum, which in itself is more than sufficient to pay for a Bailey furnace. This sum capitalised at 4% interest for 20 years amounts to over £212,000. Bailey furnace construction permits operation with minimum excess air over a very wide range of load, so that the saving in fan power debit alone gives a very handsome return on capital invested.

Criticism might be made that the limits are too wide in the foregoing example, but even if operation is assumed with 60% excess air, then the unnecessary fan power expenditure is £2,840 per annum, which when capitalised amounts to £84,570. However, when it is realised that this fan power debit is one of the smallest items entering into the balance sheet, it will be obvious that Bailey furnace construction is in the last analysis the cheapest construction which can be installed.

(For convenience we reproduce the charts from our Nos. 1 and 2 advertisements in this series, showing the relationship between excess air and CO_2 and weight of air for combustion.)

This is the third of a series of three advertisements

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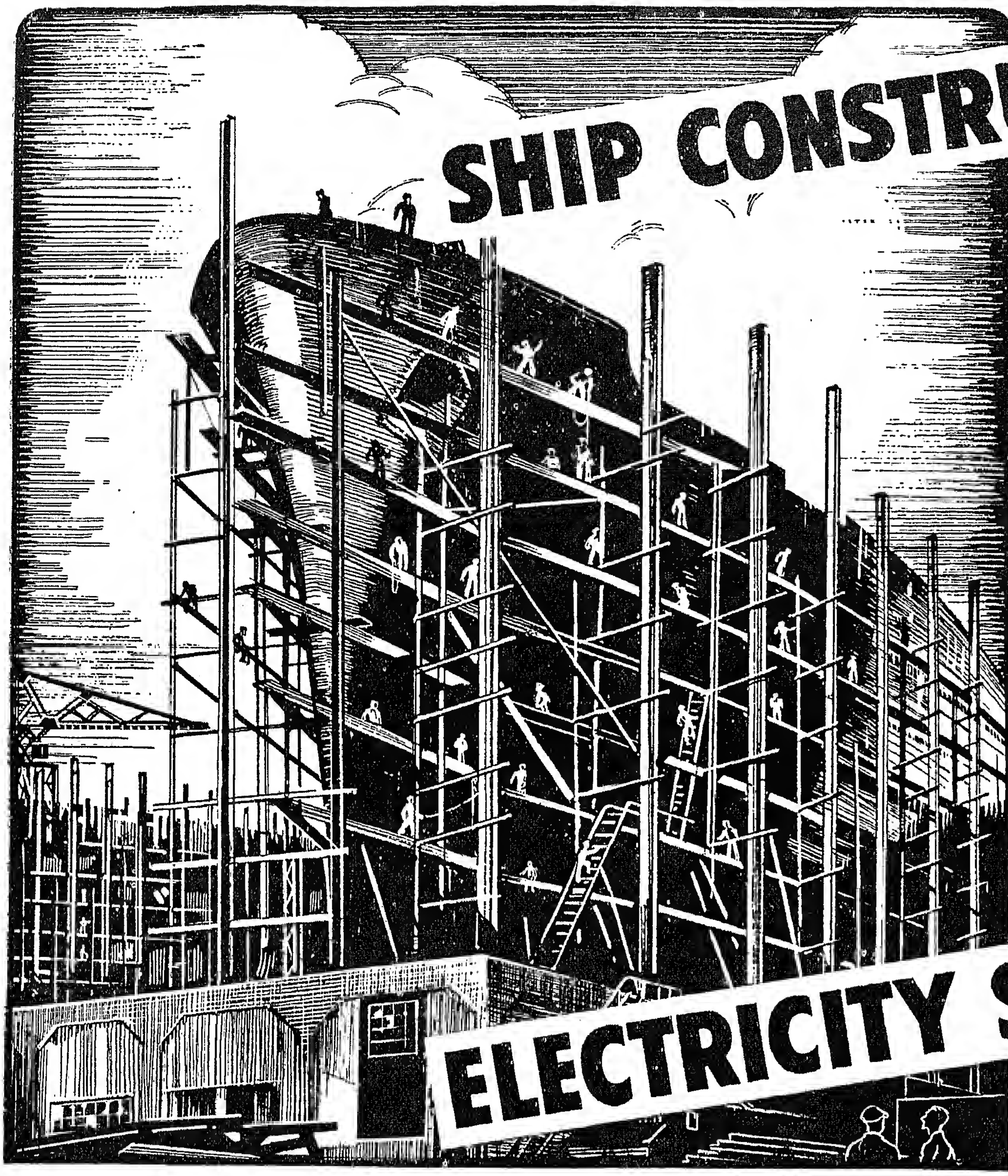

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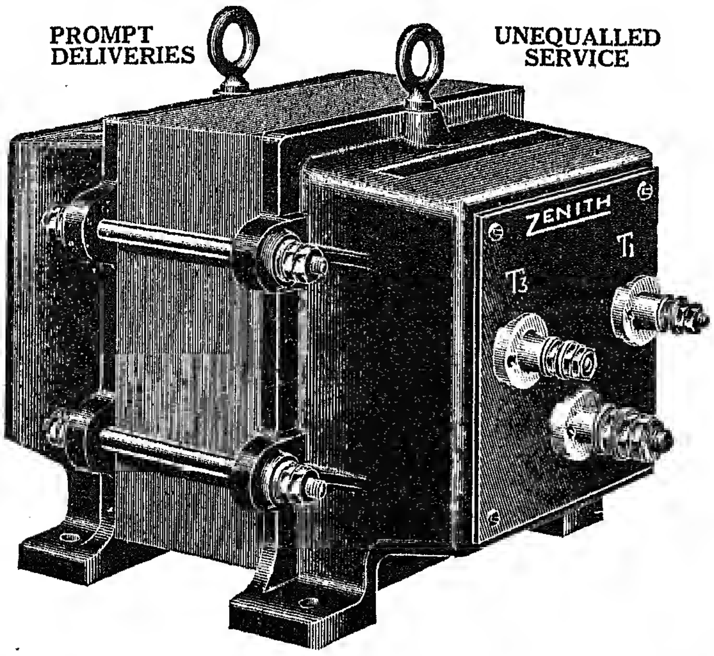

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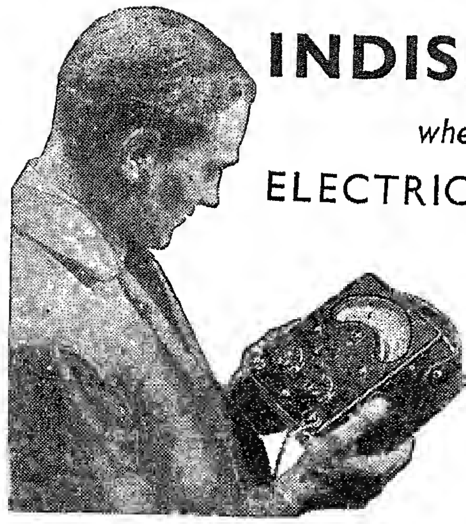

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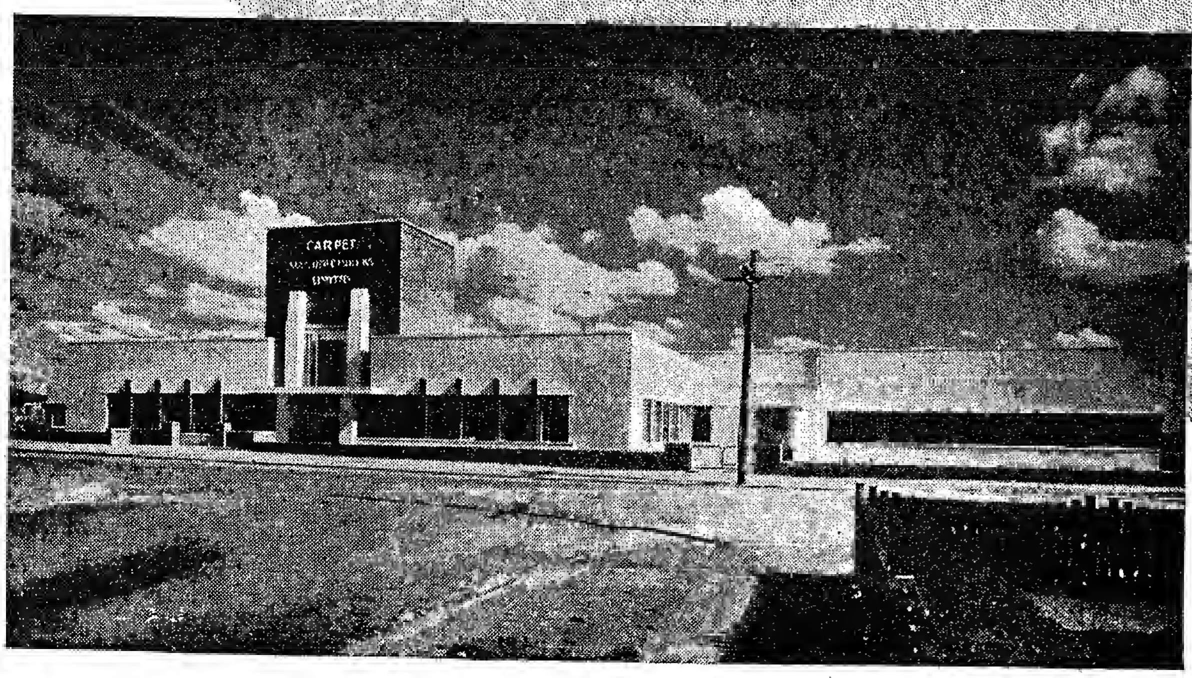

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THE JOURNAL OF THE INSTITUTION OF ELECTRICAL ENGINEERS

EDITED BY W. K. BRASHER, SECRETARY

VOL. 88. PART I (GENERAL). No. 3 MARCH 1941

THE PRESENTATION OF PAPERS AND THE DISSEMINATION OF KNOWLEDGE

If the various activities of The Institution were assessed according to their value to the members as a whole, it is certain that the preparation and presentation of papers would take high place and would probably, in normal times, be placed above all others. So long as the main object of The Institution is to facilitate exchange of information and ideas among its members, so long will the formal paper, ultimately published in the *Journal*, be valued by all. Everyone with a lively interest in his profession looks forward to the appearance of new papers both on subjects in which he is a specialist, and on subjects in which he is only interested in a general way. The ramifications of electrical science have now spread so wide that no member can attempt to follow every detail of progress, and we may be counted fortunate, therefore, in possessing an organization, supervised by the Papers Committee, which presents the available material in such a convenient form for assimilation.

There can be no question that the most pleasant and most efficient means of disseminating new knowledge is to be found in the personal contact at meetings where the subject is introduced by an author and then discussed. Owing to physical difficulties, however, it is not possible to bring together any but a small fraction of the members for this purpose, but when a paper or an abstract is published in the *Journal* it reaches most of The Institution's 20 000 members, a large number of whom take advantage of the opportunity of learning the progress made by the profession and of sharing the knowledge of new developments thus made available.

The recording of advances as they occur is desirable from every point of view. From the standpoint of the writer of a paper, impressions are most forceful and accurate if registered at the time; whereas the reader benefits from the knowledge obtained while it is current. Ideas for further progress may be lost entirely if not placed on record at the time they are suggested, and they will be much more likely to result in productive thought by the reader if published while the subject is to the fore.

And what shall be said of those public-spirited members who place their knowledge so unstintingly at the disposal of their fellows? They benefit personally in many ways. Theirs is the well-known satisfaction common in intellectual pursuits, which results from the carrying out of a piece of creative work. They have the satisfaction which comes from completion, not only of a particular design, or of a piece of research, but also of the mental processes that have resolved into an ordered scheme those nebulous, tentative ideas which started the train. The origins are obscure, but the subject develops, the paper slowly and sometimes painfully takes shape, and the results are shared by every member—the benefits in most cases by all humanity.

The preparation of a paper is not an easy task. The collection of data, the arrangement of layout and the clothing of the skeleton in literary taste, call for sacrifice of time and energy; but what better incentive could there be than the thought of helping one's fellows in that most far-reaching of all modern scientific fields covered by our great Institution.

P. D.

LOCAL CENTRE ACTIVITIES

Irish Centre.

At the meeting to be held on the 20th March a paper will be read by Mr. D. R. Fenlon, B.E., entitled "The Isolated versus the Earthed Neutral for H.T. Systems."

Mersey and North Wales (Liverpool) Centre.

It was found impracticable to hold the meeting which had been arranged for the 24th February, but arrangements have been made to hold a meeting on the 17th March, when Mr. G. F. Sinclair will read his paper on "The Trolleybus."

North-Eastern Centre (and Tees-side Sub-Centre).

The Committee have been fortunate in prevailing upon the Lord Mayor of Newcastle, accompanied by the Sheriff, to preside at the Faraday Lecture to be delivered by Mr. C. E. Fairburn on the 12th March.

As already announced, the Annual General Meeting of the Centre will be held on Monday, 21st April, and at the conclusion of the formal business the paper by Mr. W. A. Cook entitled "Outdoor Bushings—their Construction, Testing and Standardization," will be read and discussed.

Immediately following the Annual General Meeting of the Tees-side Sub-Centre on the 2nd April Mr. T. C. Gilbert is to read his paper entitled "Voltage-operated Earth-leakage Protection."

Scottish Centre (and Dundee Sub-Centre).

At the meeting of the Scottish Centre in Glasgow on the 11th February, an informal talk on "Some Aspects of Electricity Meters Act, 1936," with demonstrations and illustrated by lantern slides, was given by Mr. D. C. Gall. The meeting was well attended considering the circumstances, and an interesting discussion followed. This talk was repeated in Edinburgh on the following evening.

For the final meeting of the Sub-Centre this session on the 13th March, arrangements have been made for Mr. F. J. Hutchinson, B.Sc., to read a paper entitled "Some Aspects of the Relation between Design and Operation of a Steam Generating Station."

As it is expected that there will be several visitors from a distance at this meeting, the Committee have decided to have an informal Sub-Centre Dinner. It has been the custom in past years for representatives from the Scottish Centre to attend at least one Sub-Centre meeting in the course of the session and the Committee hope that the parent Centre will be fully represented on this occasion.

Western Centre (and West Wales (Swansea) and Devon and Cornwall Sub-Centres).

The meeting of the West Wales Sub-Centre arranged for the 18th January had unfortunately to be cancelled.

Dr. Taylor and Mr. Shotter visited Swansea on the 15th February to present the paper on "Practical Aspects of Earthing," of which they are co-authors with Mr. Fawssett and Mr. Grimmitt. A number of colliery electrical engineers were invited to the meeting.

Northern Ireland Sub-Centre.

At the March meeting of the Sub-Centre Mr. F. R. Unwin is reading a paper on "Light and Colour."

ASSOCIATE MEMBERSHIP EXAMINATION: NOVEMBER, 1940 (Home Centres)

LIST OF SUCCESSFUL CANDIDATES

(Success in this examination does not of itself constitute the candidate an Associate Member.)

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Davie, Owen Hosmer.	Quincey, Stanley Arthur.
Dawson, William.	Quinn, Joseph Francis
Dodd, Thomas Frederick.	Saunders, Joseph Brown.
Flather, Leslie.	Saxby, Francis Hugh.
Gale, Donald Henry.	Shore, Alec
Gregory, William Herbert.	Simmons, Jack.
Griffiths, Thomas Daniel.	Singh, Pal.
Halliday, Jack Hubert.	Thompson, William Alexander.
Harrison, John Michael.	Vexler, Nataniel.
Imber, Richard Charles.	Widdowson, Albert.
Lang, George Andrew.	Williamson, Drummond.
Lawrence, James Scott.	Winnard, James Guy.
Lewis, David.	Wood, William Stanley.
Major, William.	Worthington, Thomas Scott.

Part I only

Ellingham, John Henry Guy.	James, Gilbert Oliver.
Emerson, Eric.	Laidlaw, John Royston.
Hale, Anthony Peter.	Plant, Edward.
Housley, Herbert Wilfred.	Upstone, Walter Edward.
Hughes, David Alexander.	Watts, Stanley Argyle.

Part II only

Gray, Reginald Irvan.	Uren, John.

CENTRAL REGISTER OF NATIONAL SERVICE

The following summarizes the work of the Electrical Engineering Placing Panels up to the 17th February:—

Number of "orders" received	388
Vacancies represented by above orders ..	1 744
Names put forward for above vacancies ..	4 723
Confirmation of appointments received (to 14th February)	826

The above "orders" frequently contain requests for nominations to fill several vacancies and it is usual to submit the names of at least four candidates for each vacancy, because it is known that the majority of electrical engineers enrolled on the Register are already engaged on work of national importance from which their transfer is often undesirable. There is usually delay in the receipt

* This list also includes candidates who are exempt from, or who have previously passed, a part of the examination and have now passed in the remaining subjects.

of confirmation of appointments through the Register; therefore the last of the above figures does not represent the full number of vacancies which have been filled.

The Secretary of The Institution would be glad if members would assist in keeping the Institution's records up to date by informing him of any change in their addresses or employment.

SCHOLARSHIPS

The Secretary desires to draw the attention of members to the following Institution Scholarships. The closing date for receiving nominations for this year's awards is the 15th April. Any member desirous of obtaining more detailed information should apply to the Secretary.

Duddell Scholarship (value £150 per annum for 3 years).

Open to British subjects under 19 years of age on the 1st July who have passed a matriculation or equivalent examination, and who desire to take up a whole-time day course in electrical engineering.

Preference will be given to candidates whose fathers or a near relative are, or have been, members of The Institution.

Swan Memorial Scholarship (value £120 for 1 year).

For whole-time research or post-graduate work. Open to British subjects under 27 years of age on the 1st July who have taken either (*a*) a whole-time course in electrical engineering of at least 3 years and obtained a degree or diploma; or (*b*) a whole-time course in science of at least 3 years and obtained an honours degree, provided that in the final examination for such degree they have passed in "physics," or "electrochemistry," or "electrometallurgy."

Preference will be given to candidates who were born in the County Borough of Sunderland, or resided there for at least 7 years, or were educated at Sunderland Technical College.

The Council will not award this Scholarship unless it is clear that the facilities for, and the nature of, the work justify an award.

Silvanus Thompson Scholarship (value £100 per annum, plus tuition fees, for 2 years).

Open to British subjects who have served a minimum apprenticeship (or its equivalent) of 3 years at an approved works and are under 22 years of age on the 1st July, and who desire to take up a whole-time day course in electrical engineering.

William Beedie Esson Scholarship (value £120 per annum; tenable for 2 years, renewable in approved cases for a third year).

The conditions are similar to those for the Silvanus Thompson Scholarship.

ELECTIONS AND TRANSFERS

At the Ordinary Meeting of The Institution held on the 30th January, 1941, the following elections and transfers were effected:—

Elections

Associate Members

Amies, Arthur Donald E.
Arnott, John Thomson.
Atchley, Kenneth Wilmot.
Avis, William John.
Banister, Frederick Edward L.
Beasley, Herbert Anderton S.
Bell, William Henry H.
Buckle, George William V.
Chadwick, Reginald.
Clarke, John Lumsden.
Cleaver, Eric Dorington, B.Sc. (Eng.).
Cook, Leonard Oliver.
Dalton, John William.
Dick-Cleland, Alexander William A., B.Sc.
Gillhespy, James Sibbald, B.Sc.
Greaves, Frederick Redvers.
Greer, Harold Lawrence.
Heins van der Ven, Adrianus Johannes.
Houlgate, Henry John.
Jacobs, Ernest.
Jessel, Ralph, B.Sc., Ph.D.
Kumar, Harbans Lall, B.Sc.
Lewis, Joseph.
Malet-Veale, Cecil John E.
Martin, Cyril Arthur J., M.C., B.A.
Maybank, Eric Walter.
Moss, Benjamin Francis.
Murrell, Frederick Grove.
Myers, Leonard Morris, B.Sc.
Naylor, John Frederick H., B.Sc.(Eng.).
Perkins, George Karl.
Plant, George Seymour.
Preston, Stanley Jowett.
Read, Lawrence John S.
Schlesinger, Frank William, Capt., R.E.
Sharman, Arthur Edward, B.E.
Sik, George.
Smith, Robert Henry, Major, R.E.
Steggall, Henry John, B.Sc. (Eng.).
Thneyian, Yahya.
Vine, Harry Albert E.
Walker, George.
Wood, Thomas Herbert.

Associates

Broadbent, William.
Brooks, Henry Herbert.
Burford, Harry.
Churton, Marshall Edward H., Capt., R.A.O.C.
Clifton, Herbert.
Colterjohn, Albert Eric.
Cunningham, Robert.
Davidson, George Wilson.
Dunman, Fred Rowley.
Esson, John Raymond.
Evans, Percy, Sec. Lieut., R.E.
Forsdike, Leslie Albert.
Foster, Wilfrid Drewry.
Gamlen, Cuthbert George L.
Gazard, William Albert, Sec. Lieut.
Hancock, William.
Hatton-Ward, Walter Henry.
Hunter, James.
Kefford, William George.
Kelley, William Robert W.
Kelly, Francis Charles.
Lyon, David.
Mayne, Geoffrey Hollis.
Miller, Charles William.
Mitchell, William A.
Parker, Quintin Frederic.
Pope, Godfrey William B.
Purves, John Bertram.
Ross, John Harold S.
Scott, James Bryan.
Sharman, Reginald.
Speirs, Robert.
Stockbridge, Edward Rupert.
Tarr, Lancelote Exton.
Webber, Alexander.

Graduates

Baroni, Maurice Cyril.
Blascheck, Alexander Charles.
Bloxsidge, William Robert.
Bonn, Charles Douglas, B.Sc.
Burgess, Ronald Eric, B.Sc.
Canning, Francis Richard.
Carter, Hubert Lionel.
Choe, Maung Ba, B.Sc.
Clarke, Douglas.
Clay, Jack.
Clayton, Robert James, B.A.
Collins, Geoffrey Charles, B.Sc.(Eng.).
Crew, Eric William, B.Sc.
Cross, Hector William, B.Sc.
Dewhurst, Thomas Frederick.
Dickie, John Combe.
Erdos, George, B.Sc.(Eng.).
Evans, Tom Oscar, B.Sc.
Farmer, Herbert Charles.
Farrimond, Margaret (Miss).
Fletcher, James Tertius.
Fowler, Raymond Jack.
Ghose, Subhransu, M.Sc. (Eng.).
Gibbs, Harold Ernest H.
Gledhill, Frederick George, B.Sc.
Gough, George Stott.
Grapes, Gordon Tremelling, B.Sc.(Eng.).
Hall, John Edward, B.Sc. (Eng.).
Hawes, Douglas Owen, B.Sc. (Eng.).
Higgins, Arthur Redvers.
Hind, Robin Cyril, B.Sc.
Hughes-Caley, Geoffrey Maurice.
Hunter, James Muir.
Jones, Bernard.
Joshi, Vaman Ambadas, B.Sc.
Kasinathan, Natesa, M.A., M.Sc.
Kershaw, Wilfred.
Kitiyakara, Suvinit, B.Sc.
Krishnan, Lakshmikantan Muthu, M.A., M.Sc.
Large, Gordon Jack.
Leece, Alan Anderson.
Lintern, Albert Herbert.
Littler, Clifford.
Long, Ernest Keith, B.Sc. Tech.
MacCarthy, Denis.
Marchant, Mervyn Kenneth, B.Sc.
Meredith, Albert Edwin.

Graduates—continued

Milne, George Bernard C.
Mitchell, Cyril John.
Morgan, James, B.Sc.
Murti, M. S. Rininivasa, B.E.
Paterson, Frederick Roy.
Pattenden, Barney, B.Sc. (Eng.).
Payne, Ivan Salisbury, B.Sc. (Eng.).
Pennell, Vernon Barclay.
Peregrine, Edgar Phillips, B.Sc.
Pugh, John.
Pullinger, William Wallis, B.A.Sc.
Richardson, John Joseph P.
Rumble, Reginald Vincent, B.Sc.(Eng.).
Rumbold, William George.
Shah, Jivaraj Valchand, B.Sc.
Shankland, James Henderson. B.Sc.
Sherlock, Terence Dent, B.Sc.
Shipley, Jack.
Southerton, Thomas Henry.
Spooncer, Ronald Clifford, B.A.
Sullivan, Rowland Wilfred J., B.Sc.
Taylor, Harry, B.Sc.
Timpson, Thomas, B.Sc. (Eng.).
Tin, Maung Maung.
Townsend, Frederick Henry.
Trivedi, Prabha Shanker G., B.Sc.
West, Robert Alward.
Willmer, Reginald William, B.Sc.(Eng.).
Williams, Garnet Montague E.
Williams, Richard Geoffrey, B.A.
Woolger, Stuart Douglas.

Students

Abbott, Robert.
Afnan, Foad, B.A.
Allen, John.
Allen, John Reginald.
Andrews, Walter Agnew.
Aseervatham, Samuel D.
Atkins, Leonard Edward.
Axson, Thomas.
Balfour, Campbell.
Bannister, Godfrey Holtby.
Barker, Billie.
Barlow, Harry.
Barnes, Harold Ernest.
Bastable, Arthur Cyprian.
Beattie, John Matteson.
Bhalla, Bal Raj.
Bhardvaj, Ramesh Chandra.
Bird, John Epitaux.
Birkinshaw, Ronald Joseph.
Bolton, Eric.
Boothroyd, Haydn.
Borodin, Simon Serge.
Bossenger, Neville Thomas.
Brice, Seton Seward.
Bridge, Albert.
Brown, Donald Hamilton.
Brown, Thomas George.
Bruce, Andrew.
Budd, Arthur James.
Burrett, Leonard William.
Burton, Noel Ivan.
Butler, Sidney Henry.
Butt, Ernest Newton.
Cantelo, John Wilfred.
Cantwell, Brendan Gerrard.
Carpendale, Brian Maxwell M.
Carrington, Richard.
Castledine, Martin Henry.
Caswell, Cyril William.
Chakravarty, Satyendra Nath, B.Sc.
Chapman, Vincent Frank.
Chappel, George Alfred.
Chisnall, Cedric Reginald J.
Choppen, Raymond George W.
Coates, Kenneth Arthur J.
Collins, John Frederick.
Collins, John Henry.
Colver, Reginald Douglas.
Comfort, Sidney Richard G.
Cooper, Stanley Birkett.
Copsley, Roy Beaumont C.
Corlett, Eric George.
Coward, James.
Crook, Frank.
Cuthbert, Dennis Hicks.
Darton, Roy Vincent.
Davey, Cyril Norman.
Davey, John Newton.
Davies, William.
De Franck, Alexander Victor.
De Fry, Carl Hubert.
De Mel, Widanelage Percy D.
Densem, Ivan Ryland.
De Vas, Jacques Pinard, B.Sc.(Eng.).
Dewhurst, Donald Bate.
Dhanda, Om Prakash.
Dordi, Sohrab Nariman.
Douglas, Gordon Charles G.
Driver, Peter Hilton.
Duguid, David Robertson.
Dryden, Peter Wilfred.
Edwards, Eric.
Edwards, Leonard Geoffrey N.
Elliott, Gerald Stanley.
Ellis, Donald George.
Ellis, James Douglas.
Erskine, Russell Arcot.
Fawkes, Cecil.
Felix, Michael Otto.
Fenton, Paul.
Flatt, Philip Henry, B.Sc.
Fletcher, Stephen Baldwin D.
Francis, Edgar Antony.
Gallagher, William Joseph.
Ganga, Raju Kuncham.
Gates, Walter Augustus S.
Ghatak, Nirmal Kumar.
Ghose, Hrishikesh, B.Sc.
Gidney, Hugh Groves.
Gill, Frederick Denis.
Glanville, John Herbert.
Gledhill, George Arthur.
Goodchild, John Richard.
Gotheridge, Ivor.
Grover, Edward Arthur.
Hafter, Gordon Henry.
Hamilton, James.
Hamilton, Robert Scott.
Harding Raymond Lewis T.
Harper, William Glass W.
Harvey, Peter James.

Students—continued

Havens, Ivor Edwin.
Hayman, William Henry S.
Headley, Ronald St. Clair S.
Heathcock, George Ernest G.
Hersant, Joseph James.
Hinks, William Leonard W.
Hobley, Edward Brian.
Hodgkinson, Wilfrid Arthur.
Hoey, Gordon.
Isherwood, Charles Fitton.
Jackson, Edward Temple V.
Jitts, Edward Frederic.
Jones, Frank William.
Kabbert, William John.
Kagatey, Kazi Bahadur.
Kalyanasundaram, Apathodavana, B.E.
Kandasamy, Veeravagu.
Kar, Mriganka Mohan, B.Sc.
Keedwell, Elmer James.
Kelsall, James Edward.
Kemp, William.
Kilby, Donald William.
Kishen, R. Lachminarayan.
Knight, Ronald Newbrook.
Komor, Peter Sandor.
Lamb, James.
Lambert, Harold Brian.
Langham, Jack Kenneth.
Leach, Kenneth Gordon.
Lederer, Leo George.
Lednor, Basil.
Leevers, Jack Harry.
Lessels, Allan Henderson.
Lewis, Colin Arthur.
Lochen, Harold.
Lord, Arthur Valentine.
Lory, Norman Alexander.
Low, John Jackson.
Lyon, Walter.
McColl, Ian Alistair.
McGlone, Cyril Michael.
Mackey, Patrick Joseph.
McKillop, Alistair Neil.
MacMahon, Pierre Jean.
McWilliams, Allan Arthur.
Makins, Peter Gordon.
Malhotra, Mulk Raj.
Markham, Michael Frank.
Marsh, Arthur Williams.
Marshall, John.
Martin, John Henry.
Maynard, John Kenneth.
Meadows, Ross William.
Medhurst, Douglas Peter.
Menzler, Maurice Leslie.
Millett, Cyril Desmond.
Milner, Peter Marshall.
Milsted, Roy.
Misra, Shiva Behari.
Mookerjee, Krishna Kumar.
Morris, Donald John.
Morris, Henry.
Narain, Onkar.
Narayanasami, S. D.
Nash, Thomas Gifford.
Neary, Patrick Verdon.
Neilson, Arthur Christian.
Nelson, John Hawley.
Noble, Basil.
Norman, Ronald Frank.
Norris, John Albert.
Norris, Norman David.
Northrop, Edgar Waite.
Nunn, Leonard Charles.
Odell, Harold Arthur.
Owen, Victor Thomas.
Owens, Kenneth Emrys.
Pai, Divakar Guna, B.Sc. (Eng.).
Parr, Richard Geoffrey.
Pearson, John Alan.
Pearson, Roger Brook.
Perkins, Frank Douglas.
Pickthall, Arthur Henry.
Potok, Nachemia.
Prakash, Chandra.
Price, Hugh Longueville.
Pymm, Frank Henry.
Rake, Frederick John.
Rankin, John.
Richardson, Edward Gregory.
Richardson, Frederick Charles.
Roberts, Eric.
Rogers, Reece Francis.
Roscoe, Fred.
Ruth, Henry.
Salt, Joseph Merrie.
Sands, Harold John.
Sardana, Prabh Diyal.
Savage, Leonard Charles.
Saxena, Yogesh Chandra.
Schutt, Hugo Joseph.
Shah, Kanchanlal Hiralal.
Shah, Natverlal Maganlal.
Shamash, Solomon Joseph.
Sharp, Frank Allen.
Sharpe, Alan.
Shukla, Dip Chandra.
Simmonds, Kenneth Reginald.
Simpson, Jack William N.
Singh, Gurmakh Sachdev.
Singlehurst, Dennis Samuel.
Singleton, Joseph.
Sircar, Chandi Charan.
Smith, Gordon Shirley.
Smith, Norman Jesse.
Smith, Ronald Charles E.
Spurring, Peter William.
Stephenson, Leonard, B.Sc.
Stevens, David Roy.
Stewart, Robert Henry.
Stewart, William Thomson.
Stubbs, Douglas.
Summersbee, Stuart.
Sundararaghavan, Thiruvenkadatha Iyengar.
Tatton, Howard Henry.
Taylor, Herbert Arthur.
Taylor, Ian Lyell.
Taylor, James Bruce C., M.Sc.
Taylor, Kenneth.
Thompson, Deryck.
Tidmarsh, Maurice Ralph.
Todd, Russell John.
Topham, Frank.
Townend, Francis.
Tyson, Trevor Jack H.
Van Ocken, Antoine Henri.
Vedpathak, Shamrao Vithal.
Venkitaraman, Krishnaswamy, B.Sc.
Venn, Robert Henry D.
Venner, James Reginald.
Vonberg, Derek Daniel.
Waddington, William.
Wambeek, Alan Douglas M.
Warnock, William Thomson.
Wax, Martin Philip.
Westwood, Philip.
Wharhirst, Clement John.
Wheatley, Peter Kenneth.
Wheldon, Norman Robert.
White, Lawrence Edwin.

Students—continued

Whitlock, Colin.
Wilde, Andrew.
Wilkins, Dillwyn.
Wilkins, Kenneth.
Wilkins, Peter Granville.
Wilkinson, John Charles W.
Williamson, Joseph.
Williamson, Leonard Alfred.
Wilson, Arthur.
Wilson, George Arthur.
Winter, James Laurence.
Woodley, John Norman L.
Woods, George Banks.
Yanus, George Alexander.
Yerbury, George Augustus.

Transfers

Associate Member to Member

Affleck, William Ellis.
Britton, Charlie Alistair, M.Eng.
Clarke, Hugh, Major, M.Sc. (Eng.), Major, R.A.
Cockcroft, John Douglas, M.A., M.Sc.(Tech.), Ph.D., F.R.S.
Cole, William Beale.
Franklin, Ralph Herbert, B.Sc.(Eng.).
Freeth, Lancelot Gerhard.
Greenwood, Leslie.
Grinsted, William Herbert.
Holmes, Cyril Thomas.
Husband, Sidney John.
Jackson, Percy Howard.
Metcalf, Bernard Leslie, B.Sc.
Miller, Reginald Charles.
Mumford, Albert Henry, B.Sc. (Eng.).
Ross, Tascar Alan, O.B.E.
Ross, Thomas Wylie.
Smith, Norman Turner.
Wells Harold Charles.

Associate to Associate Member

Clark, Frederick Charles W.
Dunster, Basil Newport.
Harries, John Vaughan.
Holmes, Robert Gerlan D.
Pitt, Frank Ernest.
Pluck, Arthur Durell.
Sajnani, Narain Bansiram, B.Sc.
Stowers, William Claud.
Wheeler, Edmund Frank.

Graduate to Associate Member

Adams, Robert Whitehouse, M.Sc.
Baber, Frederick James.
Birch, Frederic Henry, B.Sc. (Eng.).
Birkett, George William A.
Boag, John Wilson, B.Sc.
Boden, George Harry.
Bourne, George Ronald.
Bradley, Reuben Stephen.
Bridgwood, Thomas Graham, B.Sc.
Brown, Robert Ross B., B.A., B.Sc.
Cheetham, William Ernest.
Cooper, Alan Burton, B.Sc. (Eng.).
Corbett, Philip Jack.
Dalgleish, John Girvan, B.Sc. (Eng.).
Davis, John Hancock.
De Mel, Cecil Howard J.
Draper, John.
Dyson, Edgar Veary.
England, Robert Hassall.
Fairfield, Christopher Leonard G., B.A.
Fardon, George Edward.
Foot, James, B.A.
Frost, Alan C. H., B.Sc. (Eng.).
Garrity, Harold Andrew, Pilot Officer, R.A.F. (V.R.).
Ginn, James William.
Griffiths, George Raymond.
Grove, David Stevenson.
Hack, Jack.
Haigh, Frederick Roebuck, B.Sc.
Hanna, Matthew.
Harrison-Watson, Norman John, B.Eng.
Hayes, Edward William.
Henley, John Allan, M.Sc. (Eng.).
Hiley, Stephen Gould.
Hunter, Ian Wilson.
Hurn, Mark, B.Sc.(Eng.).
Jinks, Cyril Ernest, B.Sc. (Eng.).

Graduate to Associate Member—continued

Johnson, Harold Bell, Sec. Lieut., B.Sc., R.A.
Kennedy, Edgar James, Capt., R. Signals.
Kinder, Ralph Noel, Sub-Lieut. (E.), R.N.V.R.
Lugg, John Victor.
Masters, William England.
Merrill, Frederick Henry, B.Eng.
Moat, Eric Bert.
Nicolson, Torquil, B.Sc.
Nield, Cyril.
Oliver, George Francis N., B.A.
Parr, William Henry Tuckett.
Parton, John Edwin, B.Sc., Ph.D.
Paul, Stanley Walter.
Pike, Allan Robert, B.Sc. (Eng.).
Pilkington, Basil Kenneth.
Price, Ronald Hartley.
Prosser, Harold Stanley, B.Sc.
Raine, John Stanley.
Ramsay, William Craigie.
Ranson, George Stanley, B.Sc.
Read, Richard Alfred.
Samra, Farid Daoud, B.Sc.
Sanders, John Campbell M., B.Sc.(Eng.).
Scott, Colonel Conroy.
Shires, Thomas Atherton.
Shields, Ronald Frederick, Capt., R.A.O.C.
Siddaway, Thomas.
Smallman, Peter Douglas.
Smillie, Ronald.
Stilwell, Reginald Charles.
Sumner, John.
Swift, Frederick Garcia.
Turner, Leonard.
Varma, Hans Raj.
Watson, Thomas Henry.
Watts, Frank Gullett, B.Sc. (Eng.).
Weller, Cyril William.
Williams, Alfred Henry.

Student to Associate Member

Furnell, Percy Gawayne, B.Eng.

Student to Associate

Reynolds, Stanley Thomas M.

The following transfers were also effected by the Council at their meeting held on the 2nd January, 1941:—

Student to Graduate

Abraham, Norman Alexander.
Bent, Charles Reichel.
Brink, Gerrard Edgar P.
Brinkworth, Roland Riddle, B.Sc.
Burn, Kenneth William.
Chalmers, Rodney.
Jordan, Eric William T.
Langham, Eric Miles.
McBride, James Maurice W., B.Sc.
McLean, Ronald Ian.
Quarmby, Raymond Barber, B.Sc.(Eng.).
Snodgrass, William Allan, B.Sc.
Smith, Jack Macfarlane.
Smith, James Pearson.

In addition, the following transfers were effected by the Council at their meeting held on the 30th January, 1941:—

Student to Graduate

Beadle, John Edward.
Dance, John Henney.
Flack, Donald.
Hardy, Eric Sidney.
Jamieson, William, B.Sc.
Keys, Maurice George, B.E.
Murray, Frederick Herbert, B.Sc.(Eng.).
Parlour, John Huxley.
Pinson, John Lloyd.
Sheard, Leslie.
Shelley, Leslie Hillback.
Stefanelli, Raffaele Giuseppe F.
Wrede, Dennis Frederick.

PROCEEDINGS OF THE INSTITUTION

961ST ORDINARY MEETING, 2ND JANUARY, 1941

Mr. J. R. Beard, M.Sc., President, took the chair at 12.30 p.m.

The minutes of the Ordinary Meeting held on the 14th November, 1940, were taken as read and were confirmed and signed.

Two lists of candidates for election and transfer, approved by the Council for ballot, were taken as read and were ordered to be suspended in the Hall.

The meeting then terminated.

962ND ORDINARY MEETING, 30TH JANUARY, 1941

Mr. J. R. Beard, M.Sc., President, took the chair at 12.30 p.m.

The minutes of the Ordinary Meeting held on the 2nd January, 1941, were taken as read and were confirmed and signed.

Messrs. A. N. East and R. P. Pelerin were appointed scrutineers of the ballot for the election and transfer of the members whose names were presented at the Ordinary Meeting held on the 2nd January, and after the scrutiny the President announced that the members whose names appeared on the list (see Institution Notes, page 103) had been duly elected and transferred.

The President announced that during the period October to December, 1940, 153 donations and subscriptions to the Benevolent Fund had been received, amounting to £324. A vote of thanks was accorded to the donors.

A list of candidates for election and transfer, approved by the Council for ballot, was taken as read and was ordered to be suspended in the Hall.

The President announced that the Council had elected The Right Hon. Sir Arthur Rae Duncan, G.B.E., an Honorary Member of The Institution, and that the nineteenth award of the Faraday Medal had been made to Dr. A. P. M. Fleming, C.B.E., M.Sc., Past-President.

The President also announced that the Coopers Hill War Memorial Prize and Medal had been awarded by the Council to Mr. J. S. Forrest, M.A., B.Sc., for the paper submitted by him entitled "The Characteristics and Performance in Service of High-Voltage Porcelain Insulators."

The following list of donors to the Library was taken as read, and the thanks of the meeting were accorded to them:—Air Ministry; W. H. Allen, Sons and Co., Ltd.; American Institute of Electrical Engineers; American Society of Mechanical Engineers; ASEA Electric Co., Ltd.; Associated British Machine Tool Makers, Ltd.; Association of Engineers in Burma; Association of American Railroads (Signal Section); Association of Municipal Electrical Undertakings of South Africa and Rhodesia; Association of Supervising Electrical Engineers; the Astronomer Royal; Ateliers de Construction Oerlikon; Benn Bros., Ltd.; Bennett College, Ltd.; Blackie and Son, Ltd.; British Broadcasting Corporation; British East African Meteorological Service; British Electrical and Allied Industries Research Association; British Electrical Development Association; British Engine Boiler and Electrical Insurance Co., Ltd.; British Standards Institution; British Thomson-Houston Co., Ltd.; Cable Makers' Association; Cambridge University Press; Canadian Engineering Standards Association; Central Electricity Board; Cheap Steam, Ltd.; Civil Aeronautics Authority, U.S.A.; W. A. Coates; W. T. Cocking; Copper Development Association; B. A. Cronin; W. E. Crook; Department of Scientific and Industrial Research; Electrical Association for Women; Electricity Board for Northern Ireland; Electricity Commissioners; Electricity Supply Authority Engineers' Association of New Zealand; Electricity Supply Commission, South Africa; Electrodepositors' Technical Society; George Ellison, Ltd.; Engineering Society of China; Faraday House Electrical Engineering College; Federation of British Industries; E. R. L. Fitzpayne, B.Sc.; General Electric Co., Ltd.; E. W. Golding, M.Sc.Tech.; J. Hartmann; W. T. Henley's Telegraph Works Co., Ltd.; T. E. Herbert; F. Hope-Jones; Hull Association of Engineers; F. O. Hunt; Hydro-Electric Development, New Zealand; Hydro-Electric Power Commission of Ontario; Imperial Institute; Incorporated Association of Architects and Surveyors; Incorporated Municipal Electrical Association; Incorporated Radio Society of Great Britain; Indian and Eastern Engineer Co., Ltd.; Indian Posts and Telegraphs Department; Industrial Welfare Society; Institute of Engineers (India); Institute of Marine Engineers; Institute of Welding; Institution of Professional Civil Servants; Institution of Railway Signal Engineers; Institution of the Rubber Industry; International Standard Electric Corporation; Johnson and Phillips, Ltd.; Prof. R. O. Kapp, B.Sc.; Leeds Association of Engineers; London and Home Counties Joint Electricity Authority; Longmans, Green and Co.; R. T. Lythall; McGraw-Hill Publishing Co., Ltd.; Macmillan and Co., Ltd.; Manchester Association of Engineers; S. Mavor; Meteorological Office; Mines Department; Modern Refrigeration; Mond Nickel Co., Ltd.; H. Munro, B.Sc.; D. Murray, M.A.; Prof. S. Narayan, Sc.D.; National Bureau of Standards, U.S.A.; National Electrical Manufacturers Association; National Physical Laboratory; National Research Council, U.S.A.; George Newnes, Ltd.; New South Wales Department of Works; New Zealand Hydro-Electric Development; New Zealand Post and Telegraph Department; Patent Office; Sir Isaac Pitman and Sons, Ltd.; Plastics Press, Ltd.; C. C. Pounder; Presses Universitaires de France; Rand Water Board; E. T. A. Rapson, M.Sc.(Eng.); R.C.A. Institutes Technical Press; J. H. Reyner, B.Sc.; Royal Alfred Observatory, Mauritius; A. Rubin; H. Savage; E. and F. N. Spon, Ltd.; Surveyor General of India; The Technical Press, Ltd.; Tin Research Institute; Toronto University Engineering Society; R. P. Wallis, Ph.D.; W. Wilson, D.Sc.; G. Windred; A. T. Witts; and S. G. Wybrow.

The meeting then terminated.

EAST MIDLAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By Captain B. C. BAYLEY, M.B.E., Member.*

"THE RAPID GROWTH OF ELECTRICITY IN INDUSTRY"

(*Address delivered at* LOUGHBOROUGH, 12*th October*, 1940.)

INTRODUCTION

To have been elected Chairman of this important Sub-Centre is an honour for which I wish to express my deep sense of appreciation. Difficult as it will be to maintain the standard set by my predecessors, nevertheless, with your help in these grave times, I will do my best to uphold the traditions of this eminent position.

In his Address† last session, Mr. Allwood referred to developments in the use of electrical energy in the heavy engineering industry. It is customary for the Address of the Chairman to reflect to some extent his own experience during the years immediately preceding his election, and I therefore propose to make my main theme the industrial application of electricity as applying to the manufacture of tobacco. I think my remarks will show that my predecessor was correct in expressing the belief that this growth applies to other industries than that of engineering.

Before dealing with my main subject I should like to refer to the importance of the generating stations in the area covered by this Sub-Centre, the growth and development of which is to a large extent governed by the industrial power load they are called upon to supply.

GENERATING STATIONS

I propose to mention only four of the large stations in this area, namely those at Derby, Leicester and Nottingham and the Derbyshire and Nottinghamshire Electric Power Co.'s station at Spondon. For the year ending the 31st March, 1939, these stations sold between them a total of 771 million units (excluding export to the C.E.B.), representing an increase of 10% on the preceding 12 months, and at an average total working cost of 0·554d. per unit sold. For the year ending the 31st December, 1938, there was an average consumption of 1·52 lb. of coal per unit sent out.

Reference to the published statistics shows that the area covered by the stations mentioned, which represents about 2·5% of the total area served in Great Britain, consumes about 4·75% of the total generated in Great Britain, and the performance of the stations in the area compares very favourably with that of the stations in any other area.

I am therefore of the opinion that the industries represented in the area of the East Midland Sub-Centre are well served in respect of electricity supply by up-to-date and efficient stations. The growth of the load on these stations is an indication of the wider use of electricity in the industries in which we of this Sub-Centre are interested.

TOBACCO INDUSTRY

I have been closely associated with the tobacco manufacturing industry for the last 12 years, and I propose to outline in this Address the layout and principles followed in recent developments and in the modernization of old plant, in the hope that they will be of interest and encouragement to other industries. It will be recognized that tobacco manufacture represents a light industry, but it is typical of many industries in this district where the load comprises a large number of devices such as motors, conveyors, fans, heaters, detectors, etc., with high demands and high load-factors.

CONTINUITY OF SUPPLY

In the tobacco industry, and in fact in most industries, one of the first conditions that an electricity supply must satisfy is that it must be uninterrupted, as loss of supply, even for a short period, means loss of production and wastage of material. To be entirely free from interruption is an ideal to achieve which would lead to uneconomical expenditure on plant and cables, but a very near approach is obtained with a bulk supply from the public authority in conjunction with a private generating station.

This is the arrangement at the particular factories whose electrical installation I propose to describe, and whilst I do not suggest that two independent supplies are in general necessary, they were felt to be essential for this group of large factories. In particular, the loss of output caused by a shutdown of even 1 hour is serious, as this would be represented by many millions of cigarettes, and then there is the problem of a staff of over 9 000 who would be rendered idle by a protracted cessation of manufacture.

It is not to be concluded that I imply any unreliability of public supply, particularly when the majority of such supplies nowadays can fall back upon the national Grid should a failure occur on generating plant in the local station. The hazard is more that such public supplies, being communal, are liable to interruption from causes which are outside the control of the undertaker, or even of the C.E.B. if risk of aerial attack is included; so that if private plant is available as a standby then the contingency of a total loss of supply is prevented.

DIESEL PLANT

The standby plant referred to originally comprised two 600-b.h.p. 410-kW Diesel alternator sets generating at 6·6 kV, but with the growth of the load the capacity of this plant has recently been more than doubled by the addition of two 900-b.h.p. 630-kW sets, giving a station rating of 3 000 b.h.p. with the usual 10% overload capacity; so that it is now sufficient to supply essential services. The original two engines are each air-injection type, 6-cylinder, running at 250 r.p.m. The more recent sets are solid-injection type, 6-cylinder, at 300 r.p.m.

With the four engines now installed it is probable that this constitutes one of the largest standby plants in the country. At regular intervals the engines are run under

* Messrs. John Player and Sons.

† *Journal I.E.E.*, 1940, 86, p. 82.

load, not only in order to keep the units in good condition, but to accustom the staff to operating conditions, so as to ensure smooth working in the event of the standby services being required in an emergency.

The following are a few working-cost figures based on 26 runs per annum, each of 1 day's duration of about 12 hours, generating an average of 12 000 units per run.

Fuel used per unit generated, 0·772 lb.
Lubricating oil: rated-b.h.p.-hours run per gal., 1 580.
Total engine costs per unit generated, 0·938d.

As already indicated, this Diesel plant is a standby; it is not and cannot be run in parallel with the public supply, as interlocked high-voltage circuit-breakers are employed, which prevent the two power sources being both coupled to the busbars at the same time. The busbars may, however, be sectioned so that part of the load can be run from one supply and part from the other, should this be found necessary in an emergency.

LAYOUT OF SUBSTATIONS AND DISTRIBUTION ARRANGEMENTS

Some of us will have viewed with disappointment the electrical distribution arrangements in many factories, which suggest that no forethought has been given to the location of the substation, the layout and routes of the cables, or to the selection of the switchgear employed for controlling the circuits. While economics plays an important part, it will be generally agreed that a planned distribution scheme will in the long run give greater reliability and safety than one which is built up piecemeal. It is, of course, recognized that only in the larger factories is such planning usually practicable.

Some of the principles which have been followed at the particular factories with which I am associated will now be described.

The bulk supply from the public authority was taken at 6·6 kV, but this was later changed to 11 kV when the load demand exceeded the carrying capacity of their 6·6-kV network. At this stage it was decided to provide a main substation to receive the dual supplies from the authority at 11 kV, stepping down to 6·6 kV; to provide the standby Diesel supply at 6·6 kV; and to distribute from the substation at 6·6 kV to six factory substations, where the supply is again stepped down to 420 volts for distribution in the factories.

The substation building has been designed with full recognition of the importance of providing, as far as practicable, against the risk of fire spreading from one section of the building to another. As the switchgear and transformers are both duplicated, and have been isolated one from the other, every precaution has been taken to prevent a complete shutdown.

The transformers and switchgear are protected by automatic and semi-automatic fire-fighting plant, details of which will be given later in this Address. The step-down substations are located as close as possible to the centre of the load, so that the run of large-cross-section low-voltage distribution copper is kept to a minimum.

It is recognized that where possible it is preferable for transformers to be placed out of doors, but unfortunately this policy is not practicable with the group of factories I have in mind, and all transformers are therefore of the indoor pattern. Bare copper connections are used for connecting between the terminals of the transformer and its switching cubicle, and from the cubicle to the distribution switchgear. It is considered that bare copper is more satisfactory than heavy low-voltage cables. Recently we have been experimenting with Pyrotenax cable, and although in the larger sections it is very difficult to install, requiring high-class labour, experience may show that in spite of its high cost it may make the preferable job.

The factory buildings have either five or seven floors, and the distribution arrangements are such that each floor is fed by low-voltage multi-core cables, the cables being run in a vertical shaft which extends the full height of the building. The trunk cable then connects to ironclad H.R.C. fuseboards, from which branch circuits are taken to rewirable-fuse type distribution boards.

Lighting in some factories is supplied by 420/105-volt lighting transformers, permitting the use of ordinary fusible cut-outs; but in the more recent installations the general lighting is by 230-volt alternating current, requiring high-rupturing-capacity fuses to protect the circuits.

ELECTRICAL DISTRIBUTION

A well-planned distribution scheme is almost as important as, and is in fact complementary to, the provisions which should be made to ensure continuity of supply to the maximum extent. In general, the guiding principle to be followed is that each important service shall have an alternative feed, and, while this may appear extravagant, it can be accomplished with very little extra expenditure on distribution copper. This condition is met by the ring-main system, as often used by public supply authorities to meet their statutory obligations, and it is this scheme which has been adopted at the particular factories with which I am associated. The arrangement is such that the 6·6-kV busbars at the main substation are divided into halves by a section switch (see Fig. 1).

Interlocks are provided on the various switches at the main and factory substations to ensure that it is impossible to parallel the Corporation supply with the standby supply if the latter is in use. The point to note, however, is that each factory substation is provided with an alternative supply from each half of the main busbars, and, further, each half of the busbars can be fed from either the Corporation or the standby plant. Continuity of supply is thus ensured to the maximum extent.

Whilst in some industries these precautions, to avoid interruptions to supply and loss of output, would not be justified, they are described here to show that, by planning the electrical distribution to a factory, freedom from shutdown may be achieved; and at the same time such planning allows proper maintenance to be given to electrical plant, which again assists in preventing breakdown.

AIR-CONDITIONING

Air-conditioning is widely used in America, and for certain manufacturing processes its advantages are such that it will undoubtedly be adopted more generally in this country. Tobacco manufacturing is an example; so for trial purposes some little time ago it was installed in a section of one of our factories. Later, after experience had been gained and adjustments made, a complete plant was installed for a new factory, to handle the whole

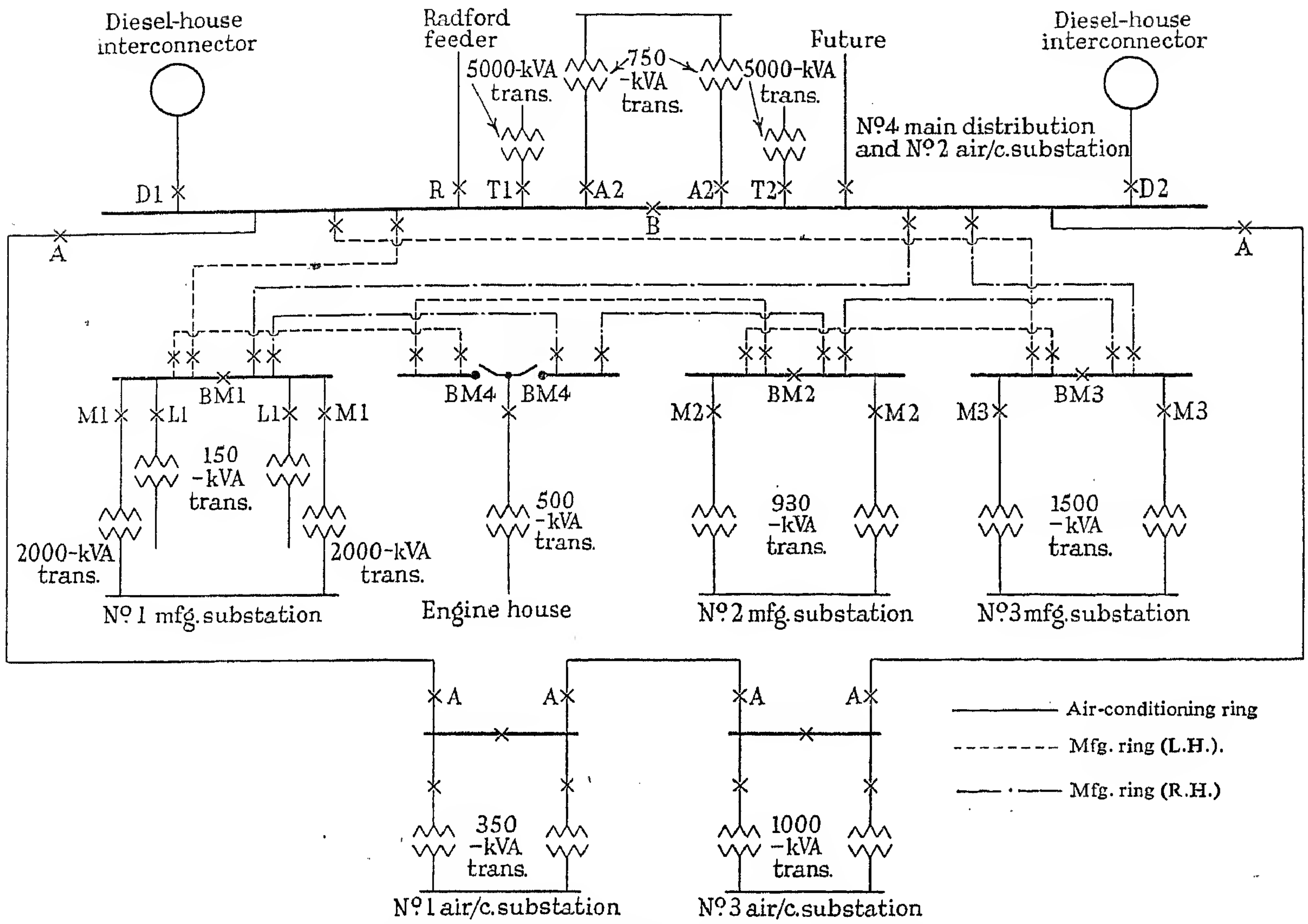

Fig. 1.—Key diagram of interlocking scheme for 6·6-kV ring mains.

Normal Running.

Corporation on both sides of busbar section: both transformers and all switches on either side of busbar section may be made alive, with the exception of diesel switches, the keys for which will be locked in No. 1 Key Exchange (busbar section open).

Diesel Emergency Running.

Supply on both sides of busbar section: to release diesel switch keys D.1 and D.2, obtain the following keys and insert them in No. 1 Key Exchange:—

- T.1. 5 000-kVA transformer, No. 4 substation.
- T.2. 5 000-kVA transformer, No. 4 substation.
- R. Radford feeder, No. 4 substation.

Diesel Maintenance Running.

Supply on left-hand side of busbar section: to release diesel switch key D.1, obtain one of each of the following keys and insert them in No. 2 Key Exchange:—

- T.1. 5 000-kVA transformer, No. 4 substation.
- B. Busbar section, No. 4 substation.
- A.2. 750-kVA transformer, No. 4 substation.
- A. Air-conditioning ring main, No. 4 substation.
- R. Radford feeder, No. 4 substation.
- L.1. 150-kVA transformer, No. 1 manufacturing substation.

Supply on left-hand side of busbar section—*continued.*

- M.1. 2 000-kVA transformer, No. 1 manufacturing substation.
- B.M.1. Busbar section, No. 1 manufacturing substation.
- M.2. 930-kVA transformer, No. 2 manufacturing substation.
- B.M.2. Busbar section, No. 2 manufacturing substation.
- M.3. 1 500-k.V.A. transformer, No. 3 manufacturing substation.
- B.M.3. Busbar section, No. 3 manufacturing substation.
- B.M.4. Busbar section, engine room.

Supply on right-hand side of busbar section: to release diesel switch key D.2, obtain one of each of the following keys and insert them in No. 3 Key Exchange:—

- T.2. 5 000-kVA transformer, No. 4 substation.
- B. Busbar section, No. 4 substation.
- A.2. 750-kVA transformer, No. 4 substation.
- A. Air-conditioning ring main, No. 4 substation.
- L.1. 150-kVA transformer, No. 1 manufacturing substation.
- M.1. 2 000-kVA transformer, No. 1 manufacturing substation.
- B.M.1. Busbar section, No. 1 manufacturing substation.
- M.2. 930-kVA transformer, No. 2 manufacturing substation.
- B.M.2. Busbar section, No. 2 manufacturing substation.
- M.3. 1 500-kVA transformer, No. 3 manufacturing substation.
- B.M.3. Busbar section, No. 3 manufacturing substation.
- B.M.4. Busbar section, engine room.

building. In this plant the air is washed, humidified or de-humidified, heated or cooled by refrigeration, and then evenly distributed. The building is fitted with double windows, kept permanently locked. This plan avoids excessive losses.

The plant is arranged for automatic control of temperature and humidity, and the method employed is known as the dew-point control. With this control the dew point, or saturation temperature of the air, is automatically controlled by means of a thermostat exposed to the air at the instant of saturation in the conditioning machine itself. The saturated air leaves the conditioning machine in rectangular trunking, and the humidity and temperature of the air entering the room are governed by a combined controller and recording hygrostat and thermostat, the air passing through suitable steam heaters where the dry-bulb temperature is increased sufficiently to establish the required dry-bulb temperature in the rooms, the humidity being controlled by the hygrostat. The hygrostat operates volume dampers in the main air trunking, allowing saturated air to be bypassed round the heater and to mix with the dry air to give the required humidity. The plant thoroughly washes and cleanses the air, and distributes it evenly throughout the building.

In this particular installation a rather interesting method of refrigeration has been utilized. As the volume of air required to deal with this building is considerable, in warm weather a large amount of cooled water is necessary at temperatures which are unobtainable without refrigeration. In place of the more usual chemical refrigerants, such as

ammonia, Freon, methyl chloride, etc., the last two of which are used in other factories on small plants, a vacuum refrigeration system was adopted for the new factory without recourse to chemical reaction. This system, which is of recent development, is one in which the water to be cooled is fed into a flash chamber, which is maintained under a very high vacuum and operated by steam jets. Owing to the very high vacuum and consequent low temperature, the temperature of the incoming warm water is reduced by some 4–6 deg. F. by a boiling process. A small percentage of water is flashed off in the form of steam during this process, the temperature of the water being determined by that corresponding to the vacuum in the flash chamber.

The mixture of the operating steam and vapour flashed is discharged into a condenser through which passes cooled water from a cooling tower. All the steam is condensed and returned to the boiler as make-up.

The total volume of air that the plant will handle is 433 000 cu. ft. per min. The total horse-power of motors employed, including standby machines, is about 1 000 b.h.p. The total steam consumption for the complete plant is naturally at its highest in the summer time when the refrigeration is in operation, and is 20 000 lb. per hour. The main fan motors, of which there are 6, are a.c. commutator motors of 42 b.h.p. and 60 b.h.p. with a 2 : 1 speed ratio, the motor speeds being 1 000 to 500 r.p.m.

Once air-conditioning has been installed it becomes an essential service which must not be shut down, and for this reason the air-conditioning load is supplied by an independent ring main and separate duplicate 6 600/420-volt step-down transformers. The total load of this air-conditioning plant, and of other smaller conditioning plants, is incidentally about 31 % of the total factory maximum demand under warm-weather conditions, with a consumption equal to about 40 % of the total.

SHORT-CIRCUIT STUDY

While it was conceded earlier that tobacco manufacture is not a heavy industry, the maximum electrical power demand is relatively high, as is to be expected in many large factories where the applications include electrically-driven process machines, some 50 lifts, heating, lighting, and, in this particular case, air-conditioning. Such a load might represent 5 000 kW, but it would be spread over several buildings taking between 350 and 2 000 kW each. This could be regarded as typical of many industries in this area where power is used at 400/440 volts and supplied through step-down transformers whose aggregate capacity ranges between the figures mentioned.

Now, transformers of 500–1 500 kVA capacity give a low-voltage short-circuit output of between 10 000 and 30 000 kVA on the basis of 4 % transformer reactance, and a short-circuit level of 150 MVA on the high-voltage side. Here then is a fresh problem, as while 10/15-MVA tested switchgear for operation at 400/440 volts is obtainable, gear for higher ratings is costly, and dangerous conditions may arise if r.m.s. short-circuit currents in excess of 25 000–40 000 amp. can flow on the occurrence of a short-circuit. It is therefore of interest to note in the Home Office Report of Electrical Accidents for 1937 a reference to a regulation that the total aggregate transformer plant installed and connected in parallel shall not exceed 1 500 kVA (Cinematograph Act).

On the basis that a maximum short-circuit of 25 MVA is the safe and economic limit, and that greater reliability of supply would be secured by a lower value, the low-voltage system has been deliberately designed so that the maximum fault energy can never exceed 15 000 kVA. This has been accomplished by limiting the size of the transformer to a maximum of 1 000 kVA wherever possible, and where it has been necessary to employ 1 500-kVA or (in one case) 2 000-kVA units then these have been connected in series with cast-in concrete reactors on the high-voltage side. The layout of the system is shown in Fig. 2.

It is considered that this is a very valuable measure of safety, as one cannot regard lightly the possibility of 100 000 peak amperes (39 000 r.m.s. amperes) flowing under fault conditions, with the accompanying mechanical and thermal effects. A still further degree of safety will be obtained now that tested air-break switchgear of 15/25 MVA rating is available, as this removes the fire hazard, however small it may be, associated with oil-break switchgear.

Before leaving this subject I would mention that all distribution cables are also capable of withstanding the current which may flow under the short-circuit conditions outlined. This is important, as I feel that the cables are often left out of the calculation. While the comments I have just made apply particularly to the 400/440-volt factory system, it will be recognized that restricting the magnitude of the short-circuit on the main 6 600-volt distribution system is equally important.

In the factories which I have mentioned, the short-circuit level on the supply authority's system was 350 MVA, but this might be increased in the future owing to growth of their generating station or to large interconnections to the grid. Fortunately we had already created a 6 600-volt network of our own, and so step-down transformers were necessary to obtain a bulk supply from the local authority, whose supply voltage was 11 kV. These transformers have the valuable advantage of acting as series reactors, and serve to limit the short-circuit on our system to 150 MVA. This value is maintained almost irrespective of any developments on the supply authority's system. In this installation there are some 60 6 600-volt switching equipments rated at 150 MVA, which are fortunately safeguarded by the reactance of the step-down transformers. In the absence of such transformers it might have been possible, on account of the development of the supply authority's system, for the short-circuit capacity to have been increased from 150 MVA to 350 MVA; the user would then have been faced with changing the switchgear at his own expense, or alternatively installing series reactors and bearing the cost of the losses. While the supply authorities are usually reasonable in these matters, and point out the greater reliability of supply which added plant affords, there is a feeling that the user in some instances is called upon to incur expenditure due to conditions over which he has no control.

REMOTE-INDICATING GEAR

The factories and stores whose electrical installation has been described, cover an area of approximately 23 acres, and have nearly $1\frac{3}{4}$ million sq. ft. of manufacturing and storage space (equivalent to 40 acres), excluding staircases,

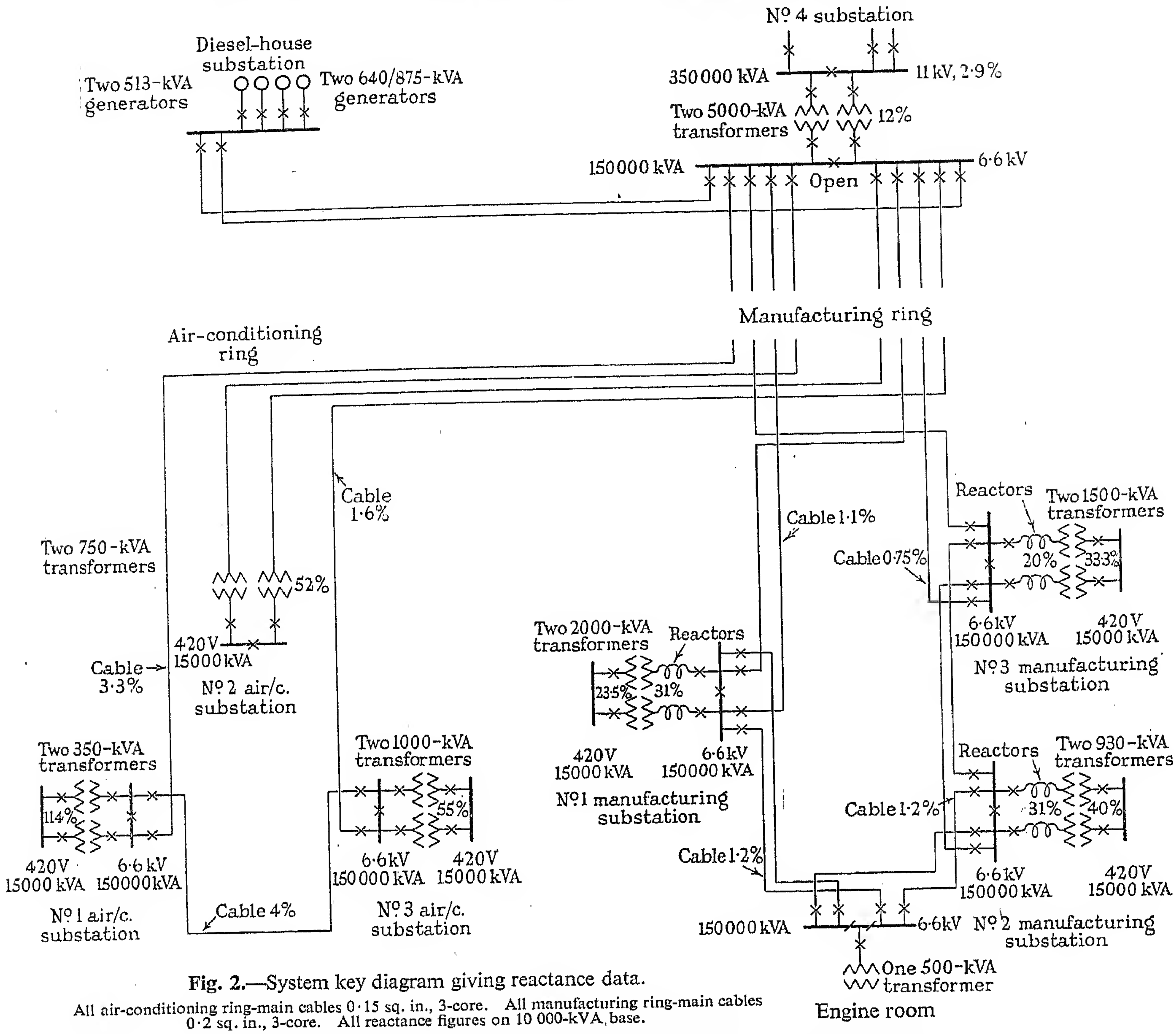

Fig. 2.—System key diagram giving reactance data.

All air-conditioning ring-main cables 0·15 sq. in., 3-core. All manufacturing ring-main cables 0·2 sq. in., 3-core. All reactance figures on 10 000-kVA base.

lifts and the like. The load for these factories is supplied by 12 step-down transformers, controlled by 60 6·6-kV switching equipments and 69 420-volt switching equipments, and fed through approximately $2\frac{1}{2}$ miles of 6·6-kV cable. This represents a fairly complicated system, comparable with that of a small public authority, and from many standpoints much more important, as an interruption of a few minutes' duration may mean a serious loss of output. For these reasons an automatic indicating diagram was considered essential, from which the position of every high-voltage circuit-breaker could be seen at a glance, and visible and audible warning given of the tripping of a switch; it was also considered desirable to have an independent telephone system to enable operating instructions to be given immediately from the main substation. This panel, which incidentally has proved of great advantage, is installed in the control room at the main substation. The central indication system installed provides a means for indicating at a central point the position of a number of 6·6-kV switchgear units located at various remote stations. The latter are connected by multi-core telephone-type cable to the indication panel at the control in the main substation, where the batteries and charging equipment necessary are situated. When a circuit-breaker changes position, as the result of either fault conditions or local control, a visual indication is given on the corresponding unit on the diagram, together with an audible alarm. Each circuit-breaker is represented on the mimic diagram by a semaphore key lamp indicator, so connected that audible and visual alarm indications are given when the positions of the indicator and of the corresponding circuit-breaker are out of agreement. Changes are "accepted" by lining-up the indicator concerned to agree with the position of the corresponding circuit-breaker.

Under normal conditions, when the diagram indicators agree with the position of the distant switchgear units, the diagram board is not illuminated.

FIRE HAZARD AND EXPLOSION

In consequence of experience gained from serious fires that have occurred of recent years in different parts of the

country, considerable attention was given to fire and explosion hazards when designing the substations, and water emulsifying plant was provided for high-voltage switchgear and transformer cubicles. The cubicles of the indoor-pattern transformers provide for oil drainage in different forms depending on site conditions, and automatic water emulsifying installations have been installed. The water pressure on this system is normally kept "on."

For the draw-out truck-type 6·6-kV circuit-breakers a shallow recess filled with graded chippings suitably drained is arranged beneath each circuit-breaker, and the main switchroom floor laid with a "fall" to drainage. In the design of the water emulsifying protection for the switchgear, sectionalizing is adopted so that in the event of a fire only that section which is affected operates. It is anticipated that this arrangement would make damage to adjacent healthy switchgear unlikely. The water projectors are so designed and placed that they protect the floor only, and do not cover the gear itself, which, as previously stated, is separately drained. In view of the above precautions and the provision of double fire-walls between the duplicated circuit-breakers, it is anticipated that interruption of supply will be avoided. The water pressure in this case is normally kept "off" and the system is therefore semi-automatic, as the attendant uses his discretion whether to turn on the water pressure to the nozzles on the section involved, or to extinguish the fire by portable fire-extinguishing apparatus, comprising 12-lb. CO_2 gas cylinders.

The alarm arrangements for both transformers and switchgear are such that aural and visual warning of a fire is given by means of either: (*a*) Electric thermostat switch installed in the transformer cubicle, operating at a predetermined temperature; or (*b*) Compressed air in the projector pipes, which, being released on operation of a control, operates electric contacts on a pressure gauge (with this arrangement the pipe system over the plant is charged with air, thus avoiding the risk of water reaching the plant due to possible leaks in the pipe joints or fittings); or (*c*) Water alarm system which, allowing water to flow to waste on operation of a control, operates a diaphragm switch.

The alarms are so arranged that indication is given on an alarm panel of the section where the fire has occurred.

METERING

We wished to ascertain the maximum kVA demand at each of our factory substations, when this maximum demand occurred, and the power factor at that time. To meet these requirements economically with a load of varying power factor, Trivector instruments were installed in each factory substation, and two Printo-Maxigraph recorders in the main substation; one to record in terms of kW, the other in terms of kVA. They were arranged so that the Maxigraphs could be plugged into any of the Trivectors in the various substations in turn. The small wiring between Trivectors and Maxigraph Recorders in the various substations was provided by extra circuits in the multi-core telephone cables on the automatic telephone system. The question of the synchronizing of the maximum-demand period was met by the use of a synchronous clock, which ensured that the maximum demands were measured over the same periods, and by starting these periods at the correct time they could be measured from hour to half-hour during the 24 hours of the day.

STATIC CONDENSERS

Apart from advantages gained on the tariff by maintaining a high power-factor on the system, considerable trouble arises from poor voltage regulation if power-factor correcting plant is not installed. On the system under discussion 50-kVAr static condensers were selected and standardized. One or more are placed at the load end of the main low-voltage feeders in the factories, and are remote push-button controlled from oil circuit-breakers in the various substations, actuating contactors mounted in an ironclad enclosure attached to the condenser tank. With this layout the attendant can readily adjust his reactive load to suit the running conditions. The arrangement has proved satisfactory in practice, and a very flexible means of dealing with peak loads. Using these condensers it has been possible to maintain a power factor of about 0·96, which, apart from improved regulation, gives a reduction of some 16% on the kVA maximum demand, showing a saving of more than £2 000 per annum.

ANNUAL CONSUMPTION

In 1929, when the bulk supply was being taken at 6·6 kV to one factory only, the annual consumption was a little under $1\frac{1}{2}$ million units; to-day it is $7\frac{1}{2}$ million units, showing an increase of nearly $5\frac{1}{2}$ times in 10 years. Owing to our having a 24-hour air-conditioning load, the load factor is very satisfactory, as is also the demand factor.

In planning the electricity supply for a group of factories having an output of such large dimensions, and representing a very considerable capital value, which includes a high percentage of excise duty, every reasonable precaution must be taken to obtain immunity from failure of supply. Therefore, duplicate main transformers are installed, ring mains used, duplicate switchgear employed with the units isolated from one another and protected from fire and explosion hazards, and finally the major portion of the load can be supplied from a standby generating plant that can be commissioned at very short notice.

CONCLUSION

In the development of electricity that has been applied to this group of factories very considerable progress has been made during the last decade. While tobacco manufacture is only a small, but, you will agree, important industry, the applications of electricity to this and other industries of similar size, such as hosiery, printing, furniture-making, etc., involve problems the solution to which requires the assistance of the public supply authority and the manufacturers; and it is only by the co-operation of these interests that the maximum benefit to all can result.

I should like to express my thanks to Messrs. John Player and Sons (Branch of the Imperial Tobacco Company of Great Britain and Ireland, Limited) for permission to use and publish some of the data in this Address.

TEES-SIDE SUB-CENTRE: CHAIRMAN'S ADDRESS

By T. S. G. SEAWARD, Associate Member.*

"SHORT-CIRCUIT CONDITIONS ON LARGE INDUSTRIAL LOW-VOLTAGE DISTRIBUTION NETWORKS"

(*Address delivered at* MIDDLESBROUGH, 12*th October*, 1940.)

INTRODUCTION

It is usual for a Chairman of a Local Centre or Sub-Centre to deal in his Address either with some matter of general interest or with some aspect of his daily professional work. Although much has been written recently on the wide topic of electrical distribution, I offer no apologies for making one branch of this subject the matter of my Address.

It is my intention to discuss the question of short-circuit conditions obtaining on large concentrated industrial low-voltage distribution networks, and present methods of calculation and testing for short-circuit currents on such networks. I also intend to place before you proposals for assessment of short-circuit values, suggestions for modifications to existing networks, and factors which should be taken into consideration in the design of new systems.

Appreciation of the dangerous condition of many existing switchgear installations has led or is leading to wholesale surveys of the position, which already have produced and will continue to produce much modification and replacement of switchgear.

Prior to the introduction of switchgear testing stations, reliance had to be placed on empirical formulae and experience in the field for developments in the design of distribution switchgear. This method has led to fallacious and optimistic estimates of switch ratings, rendering it necessary, after subsequent tests, to modify the original rating.

The work of research has considerably improved the technique employed in the design and manufacture of switchgear which has become necessary to meet the exacting demands of industry to-day. From the user's standpoint, the testing of switchgear is equally important, and establishes confidence that the equipment supplied is up to the required standard for the particular duty it may be called upon to perform.

Testing-plant activities demonstrated that the switchgear specification B.S. No. 116—1929 would require considerable revision, and a new specification (B.S. No. 116—1937) for high-voltage switchgear was issued, Part 1 covering switchgear rated up to 500 MVA and Part 2 for switchgear above 500 MVA. So far, no Specification has been issued for medium-voltage switchgear, although one is in course of preparation; and it is only recently that any attention has been paid to the proper selection of switchgear for use on medium-voltage networks.

In addition, testing experience has proved that short-circuit calculations normally made for e.h.t. networks agree within reasonable limits with the actual fault conditions which may be experienced, but on medium-voltage and low-voltage networks it has been uncertain whether the values calculated by similar methods obtain in practice. In concentrated high-voltage networks, i.e. networks with relatively short feeders, it is usual for purposes of short-circuit calculation to take into consideration only the reactance component, as the resistance component is so small as to be negligible. In lower-voltage networks, however, it becomes necessary to consider all parts of the circuit, and to classify them into resistance and reactance components.

The increase in size of low-voltage systems has brought about an increase in the values of fault currents at the low-voltage busbars, and in many cases these values are considerably higher than the ratings assigned by manufacturers of the switchgear employed. The engineer of such a network is therefore faced with the problem as to whether his existing switchgear should be replaced or modernized in order to meet the changed condition, or whether the arrangement of the network should be altered so as to reduce the short-circuit value to within the rating of the switchgear.

It is axiomatic, to a large degree, that (*a*) the greater the reliability from alternate sources, (*b*) the heavier the load density and (*c*) the less the voltage drop, the greater will the stresses become; and, in addition, the lower the voltage the greater will be the mechanical stress for a given short-circuit MVA, since this mechanical stress varies as the square of the current. It is not usually realized that the rated current in, for example, a 25-MVA 400-volt breaker is considerably greater than in one having a rating of $1\frac{1}{2}$ million kVA at 33 kV, and that arc energy is a function of current and arc resistance; and one needs little imagination to realize that a circuit-breaker made to operate on a low-voltage network of any size must be a well-designed and robust piece of apparatus.

A large installation will undoubtedly contain relatively large units of voltage-transforming plant, and as these units may have low-voltage connections of considerable cross-section it is natural that the length of these connections should be minimized in the design of the plant. It is quite common to have the transformers placed so that their low-voltage terminals are adjacent to the switchgear. This means that a relatively high short-circuit condition will obtain at the low-voltage switchgear.

CALCULATION OF SHORT-CIRCUIT CURRENT

It is generally accepted that the method used for calculating high-voltage network short-circuit conditions is

* Imperial Chemical Industries, Ltd.

unsuited to low-voltage conditions on account of incomplete data, as considerable error is introduced by extraneous impedances and inaccurate assessment of actual impedances. As previously stated, in high-voltage network calculations reasonable accuracy can be obtained by consideration only of the reactance component, but in calculations for low-voltage networks it becomes necessary to consider both the reactance and the resistance components.

The conventional way of calculating short-circuit currents on a distribution network is to determine the instantaneous symmetrical short-circuit current at zero time from the reactance and resistance components of the circuit. The use of ohmic values or equivalent ohms is advocated instead of the more common percentage method, as mistakes are liable to occur with the transfer of percentage values of plant of various capacities to a common base. In addition, the short-circuit condition is more readily obtainable at any part of the network if an impedance diagram is prepared and marked with actual ohmic values for each item of plant. For accurate calculations, the excitation conditions of the alternators should be taken into consideration, so that the open-circuit voltage of the alternator should be used instead of the service voltage.

Synchronous motors, connected to a network, will feed into the network in the event of a fall in voltage or frequency such as occurs under short-circuit conditions, and this factor should be taken into consideration if the size of these units is large enough to affect the short-circuit condition materially. It only remains to obtain the individual values of the circuit, which, when summated, will give the required short-circuit condition at any part of the network.

The evaluation of short-circuit capacity by direct calculation from plant data and system diagrams is a lengthy and tedious process. In order to simplify this work, manufacturers have constructed calculating devices (commonly known as calculating boards) for setting up network models with a view to investigating their behaviour. The simple calculating board, however, by no means gives a solution to the problem by the mere flick of a switch. Only one component of either resistance or reactance can be handled at a time, and it becomes necessary to carry out additional calculations before a final figure can be reached. The diagrams reproduced in this Address have been prepared to enable short-circuit conditions to be arrived at graphically. They have been used with considerable success, and results of a high degree of accuracy can be obtained.

Fig. 1 is a development of the well-known kW/kVA chart. Values of resistance and reactance components are shown on the vertical and horizontal axes respectively, and pivoted at the intersection of these axes is a transparent arm containing a sliding cursor. With this instrument the impedance, short-circuit MVA and power factor of a short-circuit condition can be obtained readily when the values of the resistance and reactance components are known. The cursor of the movable arm is set at the point of intersection of the known values of resistance and reactance, and the inclination of the arm gives the power factor of the fault current. The arm is then swung down to the horizontal axis to give a reading of the impedance. Short-circuit values at various voltages are scaled against the impedance figures, an arrangement which enables all

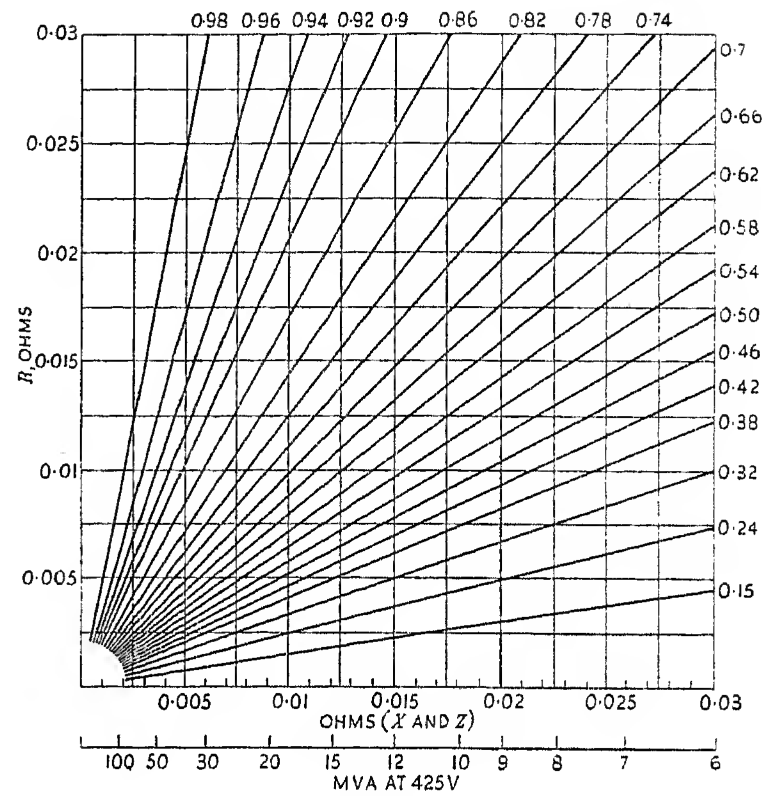

Fig. 1

the necessary data to be arrived at in the minimum of time. The chart can be adapted to suit any size of network or voltage condition by suitable choice of scale values.

Further diagrams are presented which enable short-circuit conditions to be found without the knowledge of cable resistance and reactance values. With these diagrams, in order to find the short-circuit value at a point it is only necessary to know the short-circuit value at the source, and the length and size of the cable between this source and the point of required short-circuit value. In principle, Fig. 2 is a graphical means of adding together an equivalent impedance vector of the initial short-circuit value, and the impedance vector of a given cable, and differs only from the conventional diagram in regard to the position of the origin. This change of origin enables a number of straight lines to be drawn from it in the first quadrant representing various sizes of cable, the slope of the lines being the reactance/resistance ratio of the cable. In the third quadrant a number of straight lines are drawn, also from the origin. These lines represent various power factors of the initial short-circuit values, and are divided by a circular scale of MVA, the equivalent impedance of each MVA value being drawn to the same scale as the resistance and reactance values of the first quadrant. A separate chart is used with these scales, having impedance values marked to the same scale as those used in the first quadrant, a curve relating impedance to MVA, and, in addition, a scale to indicate the final fault power factor.

The diagrams are used in the manner indicated in Fig. 3. At a point on the length scale representing the known length of cable a vertical line is drawn to intersect the line for the appropriate size of conductor in the second quadrant; a horizontal line is then drawn from this point to intersect the line in the first quadrant, also corresponding to the cable size. The distance from this point to the position of the initial short-circuit MVA figure in the third quadrant represents the total impedance and is read off on the auxiliary scale, on which the MVA value is also indicated.

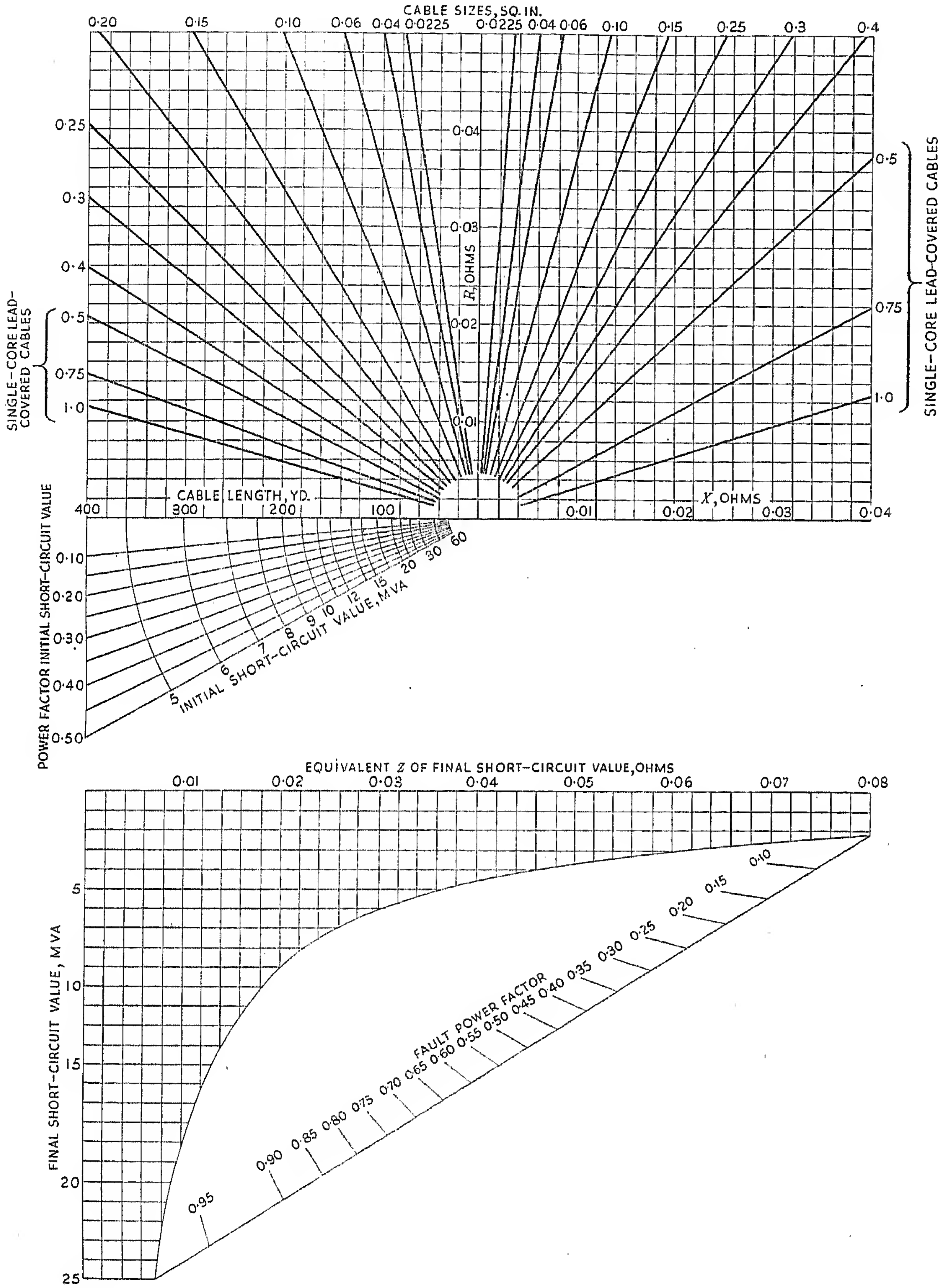

Fig. 2

The fault power factor is found by projecting a horizontal line from the extremity of the vector in the third quadrant to the power-factor scale.

The diagrams shown are constructed for 425 volts and, by using additional scales, longer cable runs can be considered; but the range can be further extended by the provision of additional scales.

SHORT-CIRCUIT TESTS

In order to check calculations, actual short-circuit tests were carried out. The purpose of the tests was to measure the fault values obtainable on a 425-volt circuit with one, two or three transformers supplied by a large power station on the busbars of which the fault value is approximately 500 MVA at 6·6 kV; and to compare the results so ob-

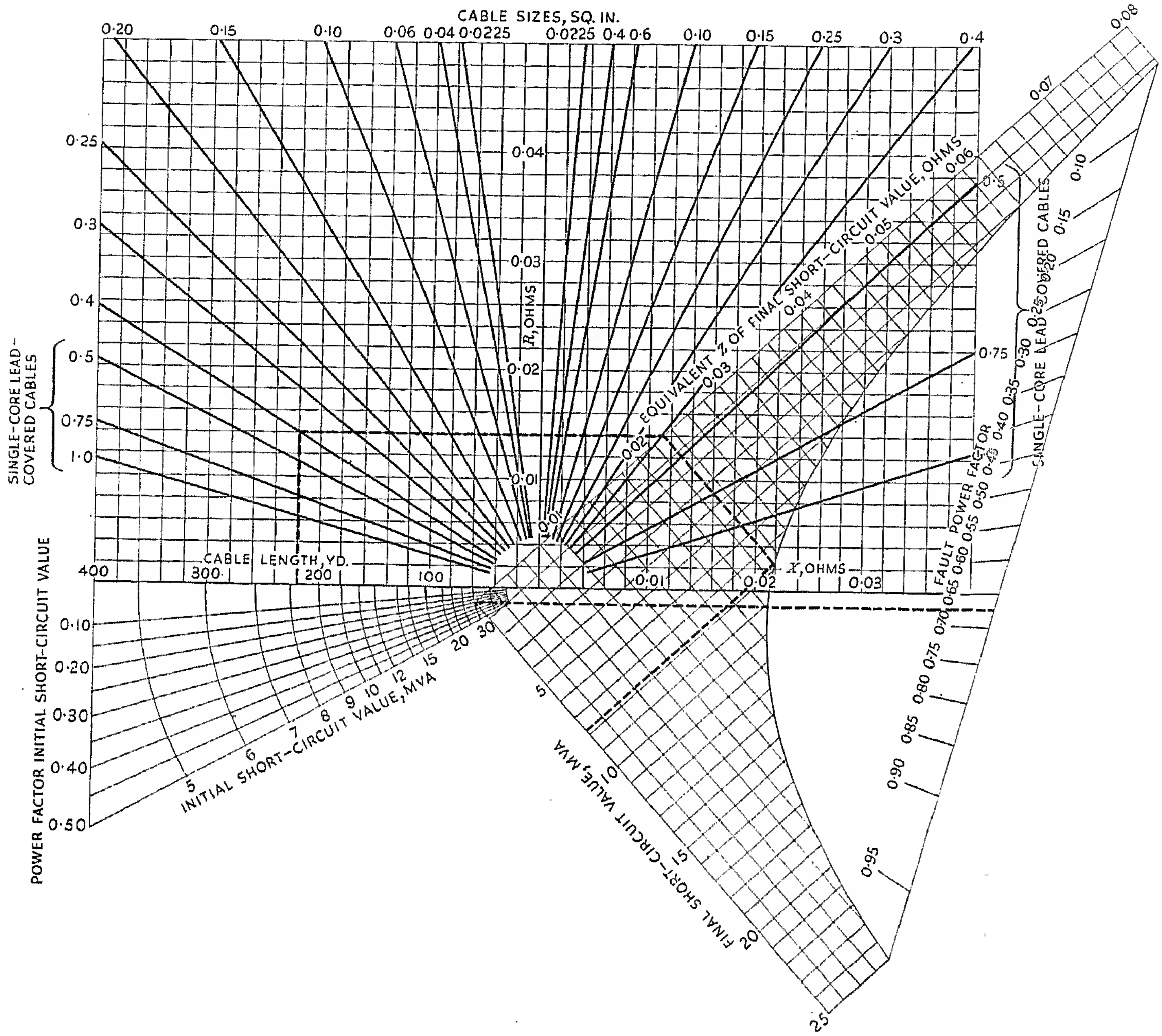

Fig. 3

tained with the values calculated from standard impedance data for the various component parts comprising the circuit.

Three 1 500-kVA transformers, each of 5·57 % impedance, were made available, being connected delta/star, with the neutral points of the low-voltage side solidly connected to earth. The high-voltage busbar was supplied from the power-station busbars by a 0·25-sq. in. 3-core 6·6-kV paper-insulated lead-covered steel-wire-armoured cable 763 yd. long. Each transformer was connected to its high-voltage switchgear through 11 ft. of 0·1-sq. in. paper-insulated lead-covered steel-wire-armoured cable and to its low-voltage switchgear by three single-core cables in parallel per phase, each consisting of 0·75-sq. in. cambric-insulated lead-covered cable. The connections between the l.v. busbars and the test circuit-breaker consisted of 2 × 0·4-sq. in. 3-core paper-insulated lead-covered steel-tape-armoured cables 12·5 yd. in length. The necessary oscillograph recording equipment consisted of a 6-element electromagnetic oscillograph and a 6-tube cathode-ray oscillograph, and the short-circuit currents were recorded from 0·00005-ohm shunts situated at the short-circuit point on the 425-volt circuit. The tests had no marked effect on the running plant or system except that there was a slight kick noticeable on the lamps when all three transformers were in circuit. In all tests a slight drop of voltage was recorded at the power station, the maximum drop being 250 volts on the high-voltage busbars. Nine tests in all were carried out; for the first eight tests the short length of 12·5 yd. of cables was in circuit, but for the ninth test a further length of 147 yd. of 0·4-sq. in. 3-core cable was added.

Table 1 gives the results of these tests, and compares these with the initial calculated values. The initial calculations did not take into consideration the very short transformer low-voltage cables, switchgear, busbars and connections. The tests showed that the calculated values were higher than the measured values by 10 % to 37 %. Investigation into this discrepancy proved that it was due to the difference between the actual values of impedance and the values normally considered for those parts of the circuit which have a predominating influence upon fault values, such as transformers and low-voltage connections. It should be noted that for Tests 2, 4 and 7 the same transformer was used as in the unit supplying the fault current. It is seen that the fault MVA decreases for subsequent tests, which appears to indicate an increase in impedance in some part of the circuit. Later examination

Table 1

Test No.	1	2	3	4	5	6	7	8	9
Transformers. . .	One T_4	One T_4	Two T_3, T_4	One T_4	Two T_3, T_4	Three T_2, T_3, T_4	One T_4	Two T_3, T_4	One, plus 147 yd. 0·4-sq. in. low-voltage cable T_3
MVA (actual) available, as shown by short-circuit test		19·75	33·8	19·2	32·8	44·2	18·0	32·0	9·3
MVA available as calculated from normal data	24·4	24·2	43·8	24·0	43·4	58·4	24·5	43·5	10·2
MVA available as calculated from impedance values measured following experience from short-circuit test ..	20·0	19·9	34·4	19·0	34·8	46·2	20·0	34·7	8·95
MVA available as calculated from impedance values obtained by recommended method of testing		20·0	34·9						9·1

of the transformer core showed that movement of the low-voltage windings had occurred as a consequence of the high mechanical stresses set up during short-circuit. The low-voltage windings had moved to such an extent that the end turn at the top of the coil was touching the core yoke, which is equivalent to an actual movement of $2\frac{1}{2}$ in. An impedance test on this unit showed that the impedance had increased by 20%. It is not generally realized that transformers may vary in impedance according to their age and the duty to which they have been subjected, and this variation should be taken into consideration when looking into short-circuit conditions on existing low-voltage networks. Incidentally, where a transformer has handled fault current an impedance test of the unit will indicate its condition.

The accurate assessment of short-circuit current entails lengthy and laborious calculations, and it was thought that an endeavour should be made to devise some simple method of testing. The ideal method would include: (*a*) all impedance between the source e.m.f. and the short-circuit; and (*b*) the relationship between the effective resistance and the reactance included in (*a*), which will also give the power factor of the fault current.

A simple method which has been adopted with considerable success, fulfils these conditions and has been found to compare reasonably closely with the actual short-circuit tests previously mentioned. It includes all the extraneous impedances, special cable and busbar arrangements which otherwise require lengthy calculation. In this manner, a typical reduction factor covering these extraneous impedances can be obtained for any particular circuit, and this factor could be applied to the future design of a similar type of layout.

The method is a voltage-drop test. When two similar transformers are energized from the high-voltage network only but with their neutrals connected together, a voltmeter connected between the two transformers on similar phases will read zero. If, however, one transformer is loaded, the meter will indicate the drop in voltage between the paralleling point on the high-voltage side and the point of contact of the voltmeter lead on the low-voltage side, and this drop will be governed by the impedance of the transformer and of all connections and circuit conditions in this zone. It is necessary to observe also the load current, and from these two readings the impedance can readily be obtained. The same applies to cables. Where two or more cables are laid in parallel and one can be made alive but unloaded, the voltage drop can be measured in relation to the load current, and the impedance easily calculated. It is, of course, essential that no current be drawn from the circuit inside the test zone, i.e. that portion of the circuit on which the impedance is required. In this manner, it is seen that the test can be made to cover an extensive cable system and can also be made to include transformers in circuit. The test cannot be applied to alternators, as there does not appear to be a method of measuring the angular displacement of the alternator vectors.

The extent of the test is limited only by the necessity for separating feeders and transformers from the network under test to act as potential references, provided that all current in the circuit flows from end to end of that circuit. Therefore it is possible to separate a high-voltage feeder together with a transformer from a similar remaining circuit. With these supplied from a power station, it is possible to measure values of this remaining circuit from the power station to the low-voltage apparatus. It remains

only to add the impedance of the alternators (or other source of supply) to obtain the total impedance values for the whole circuit.

So far it has been assumed that a spare transformer or cable has been available to carry the unloaded reference voltage. If this is not possible there are two alternative methods of obtaining this reference voltage. The first alternative is by means of a temporary line laid for the purpose. It is necessary that the resistance of this line should be low in relation to that of the test meter. A protective pilot cable or telephone cable can be used for this circuit, but care must be taken that there are no transformers in the circuit as if there are there will be change in phase angle. The second alternative necessitates the use of a separate potential reference, but it is not recommended as it might require some phase-angle correction apparatus. In general, the use of a spare feeder is preferable.

Only the measurement of impedance has yet been considered, but it is essential for purposes of accurate assessment of short-circuit conditions to segregate this impedance into the resistance and reactance components. It is necessary, therefore, to take measurements from which these data can be obtained. If a wattmeter is employed so that the voltage element is connected across the voltmeter connections and the current element suitably connected to measure the current causing the voltage drop, the internal resistance and the power factor of the circuit can be determined. Extensive tests have been carried out in order to determine the power factor, the reactance and the resistance of the circuit, but, on account of the very low power factor obtaining, such measurements by this ordinary watt-meter method are not readily practicable. Interesting phenomena were experienced in connection with the measurement of power factor and resistance by this method, and it is regretted that owing to war conditions time has not been available to carry out further research into a simple and accurate method of making this measurement.

Table 1 compares the results of some of these tests with calculated figures and actual short-circuit tests.

The conclusions reached from this survey are: (*a*) Accurate fault values may be obtained by calculation if all factors are taken into consideration and the data used are accurate. (*b*) Calculations based on data normally considered give results which are very much higher than the true values. (*c*) As the actual impedance values of transformers may increase with the duty to which these transformers have been subjected during their service, it is essential that the transformer impedance values should be checked before the fault values on existing systems are reviewed. (*d*) As a small amount of cable considerably increases the impedance of a low-voltage circuit, all short connections—and especially single-core cables—should be taken into consideration. (*e*) The method of testing outlined can be used to give very close approximations to actual short-circuit conditions.

MODERNIZATION OF EXISTING SWITCHGEAR INSTALLATIONS

Under ordinary heavy-industry conditions relatively high load densities exist; and as the majority of this load is made up of high-horse-power motors operating at 400 volts, static transformer units of large kVA rating are necessary with their attendant switchgear of high short-circuit capacity. If this switchgear has been de-rated, the user is faced with direct replacement of the switchgear, or the alternative of sectionalizing the network in order to obtain a limited short-circuit condition.

Is it not possible that the question of continuity of supply is too much stressed? In order to assure immunity from interruption of supply two or more transformers may be connected in parallel, with a consequent increase in short-circuit capacity. It is usually possible to withstand a temporary interruption of supply if a fault occurs on the transformer supplying the load, and if this is permissible there seems to be no reason why extra transformer capacity over and above that required for supplying the load should be connected in circuit. If double-busbar switchgear is installed, it is quite easy to arrange a satisfactory distribution of load so that the minimum of plant is connected to each busbar. Also it may be possible to install section switches to achieve the same object, and this can usually be carried out at small expense. If the possible short-circuit kVA cannot be reduced by these means, the circuit-breakers must be replaced by proven types, and this can in most cases be effected without any modification to the fixed portion of the gear. Owing to the large stresses encountered at the lower voltages the breaker designed to withstand this heavy duty must of necessity be an expensive item, and considerable difference of opinion exists as to the advisability of fixing a limit of capacity. The apparently large and expensive circuit-breaker may be a real economy as compared with the cost of sectionalizing a network in order to reduce the possible short-circuit kVA. The choice of the circuit-breaker should rest with the consumer, and I hope that so long as there is no technical objection to such circuit-breakers the new Specification now in course of preparation will deal with circuit-breakers capable of handling a short-circuit current up to, say, 55 kA, or about 40 MVA at 425 volts.

FACTORS IN DESIGN OF INDUSTRIAL DISTRIBUTION SYSTEMS

In the design of large installations, the limits of circuit-breaker design are easily exceeded, and it is necessary to reduce to within practical limits the fault power available, either by sectionalizing, or by the method of added reactance or by the use of transforming plant of reasonable capacity.

With regard to transformer capacity, Table 2 shows the fault power obtainable at the l.v. terminals of transformers, either as single units or as a number of smaller units connected in parallel. Two conditions are shown: (*a*) neglecting high-voltage impedance, and (*b*) assuming a fault condition of 150 MVA at the h.v. terminals. It will be seen that for a 5 000-kVA transformer the high-voltage impedance reduces the fault values on the low-voltage side by 62·4 %, but in the case of the 500-kVA transformer the reduction only results in a drop of 5·5 %. These figures do not take into consideration any impedance which may be introduced in the form of connecting cables. If a transformer is of small capacity it may not be necessary to take into consideration the impedance of the high-voltage system, since the transformer will constitute the limiting feature of the circuit. As an instance, a 200-kVA

Table 2

Total of paralleled transformers, assuming 5·5% impedance	Fault MVA on l.v. side of transformer	
	Neglecting h.v. impedance	Including h.v. impedance equivalent to 150 MVA and assuming zero impedance of connecting cables
kVA		
500	9·1	8·6
1 000	18·2	16·4
1 500	27·3	23·6
2 000	36·4	29·9
3 000	54·6	40·2
4 000	72·8	48·8
5 000	91·0	56·7

transformer with 5·5% impedance cannot pass more than 3·65 MVA, no matter how large the power available on the high-voltage side of the transformer may be. A single transformer of 3 000 kVA capacity or a number of paralleled units totalling 3 000 kVA, each of 5·5% impedance when connected to a high-voltage busbar, where the short-circuit condition is 150 MVA, results in an available short-circuit capacity at the l.v. terminals of approximately 40 MVA, and I suggest that this should be the limit of size.

The employment of large units of transforming plant has been due to the development of a "low-voltage complex" with regard to motors, and this excessive concentration of power has been responsible for the high short-circuit condition of many industrial networks to-day. It therefore becomes necessary to take this into consideration in designs for future systems. The obvious solution is to increase the working voltage, and the wider use of 3 300 volts for the higher-horse-power machines is advocated. Motors of as low as 50 h.p. wound for this voltage can now be obtained.

With regard to the future design of industrial networks with concentrated load, it is recommended: (*a*) That the generation voltage should not be below 11·5 kV, and that all generators should be connected to the same switchboard with sectionalizing switches and reactors if the short-circuit condition so warrants. (*b*) That series reactors be installed between the generator switchboard and the distribution switchboards to enable switchgear of relatively low short-circuit capacity to be employed. (*c*) That h.v. switchgear at the substations be eliminated by connecting the feeders direct to the transformer terminals, unless the employment of interconnectors or high-horse-power motors at the main distribution voltage is necessary. (*d*) That the use of an intermediate voltage of 3·3 kV be adopted for motors between 50 h.p. and 400 h.p. (*e*) That the size of transformers with a secondary voltage of 425 volts be restricted to 750 kVA. (*f*) That H.R.C. fuse isolators be installed for main l.v. distribution circuits. (*g*) That wider use be made of contactor gear for 3·3-kV and 425-V circuits.

The adoption of these recommendations will tend to eliminate those conditions which, when the new British Standard Specification for low-voltage switchgear is available, might necessitate wholesale revision and modification of existing networks.

NORTHERN IRELAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By F. W. PARKINSON, Member.

"THE ELECTRICAL EQUIPMENT OF AN ALL-ELECTRIC HOSPITAL"

(Address delivered at BELFAST, *15th October*, 1940.)

INTRODUCTION

In past years short articles have appeared in various technical journals relating to hospital installations in general, and to relative special appliances in more or less detail. The purpose of this paper is to describe more fully what is involved where a hospital depends upon electricity for all service requirements. No attempt is made to deal in close detail with special appliances, information regarding these being available from various trade and other sources.

The example is a representative hospital block for medical and surgical cases, having a ground floor and three upper floors, the wards facing south and opening on to a central corridor, on the opposite side of which are located the ward kitchens, utility rooms and sanitary accommodation. An operating theatre, X-ray department, kitchen and staff dining-room are included, so that the hospital is self-contained except for the nurses' sleeping accommodation. In the typical case under consideration there are 132 beds, and the contents of the building are approximately 404 000 cu. ft. A 3-phase public supply at 400/230 volts is available from a special substation in the hospital grounds.

LIGHTING

General

For the general lighting of the wards, central fittings with large opalescent globes give a well-diffused light of low intrinsic brightness and provide an intensity of about $2\frac{1}{2}$ foot-candles at table height. These fittings are supplemented by bed-head brackets each with its own switch and so shaded that the light does not reach the eyes of a patient in a neighbouring bed. A 25-watt lamp in each provides ample light for reading. In addition, each bed has a socket-outlet for the use of the physician or surgeon in making an examination by means of the usual pattern of hand-lamp. There are provided also one or more night-lights according to the size of the ward. These consist of 15-watt amber-tinted lamps arranged inside the globes of selected fittings controlled by 2-way-and-off switches to enable either the main lighting or the night lighting to be switched on at will. Wards containing a single bed have a similar system of lighting but with the central fitting under dual control from door and bed. The night-light in this case is separately controlled from the door, being primarily for the use of the night nurse.

Corridor lighting received careful consideration in order that the lights required for all-night use should not shine through transom windows over ward doors and cause discomfort to the patients. In those cases where lighting fittings could not be fixed on the ceiling, it was necessary to install special wall fittings fixed at skirting level or so shielded that no light is transmitted through a transom. Floor lights are sometimes used for this purpose, but are somewhat inconvenient when lamps have to be renewed.

The operating theatre has good general lighting of 7–8 foot-candles, in addition to which there is a special shadowless operation fitting arranged to tilt, rise and fall, and traverse. Included under the reflector of this fitting are four 40-watt emergency lamps controlled through an automatic relay switch from an emergency battery to provide light in case of interruption of supply or failure of the operating lamp. Another important item of equipment is the viewing light by means of which an X-ray photograph can be referred to during the conduct of an operation. This consists of a metal box let flush into the wall in a convenient position, having an opal glass front against which can be hung the film to be viewed. Even distribution of light is ensured by providing not less than eight 25-watt lamps in the box. A dimming switch is fitted for varying the intensity of the light to suit films of different densities. To meet the personal preferences of surgeons, it is advisable to provide individual switches for all top lights, localized according to their use. A recent development adopted in operating-theatre switches is a mercury switch assembled in the form of an ordinary tumbler switch, which provides a safeguard against the ignition of ether vapour following the spilling or breaking of a bottle. Fittings are all totally enclosed and offer little lodgment for dust. Their design is such that any dust which settles on them can be easily removed.

The lighting of sterilizing rooms, bathrooms and sanitary accommodation presented no special problem. Values of 5–7 foot-candles are desirable, and were easily attained by means of white or glazed reflecting surfaces of ceilings and walls. All fittings are of conventional design and are totally enclosed.

The lighting of dining-rooms and other staff rooms is adequate and carried out in such a manner as to form a complete contrast to the lighting of the wards, etc., and thus assist in the relaxation so necessary to a staff whose duties are arduous and whose hours are long.

In addition to ordinary top lighting, the X-ray room is provided with a deep amber-coloured light, separately switched, which provides enough illumination to enable personnel to move safely about the room yet not enough to interfere with the examination of a patient by means of the fluorescent screen. This and other lighting points are carefully disposed so as to avoid high-voltage leads and supports.

Emergency Lighting

Excluding those mentioned in connection with the operating theatre, there are 12 emergency lights in the

large wards and stairways, which come automatically into action should the main supply fail, a fuse blow or a lamp break. These are supplied from a 50-volt, 50-ampere-hour battery located in a room set apart for it and trickle-charged through a copper-oxide rectifier. Five cells of this battery also serve as a standby for the call system.

The total number of lighting points, including socket-outlets, is nearly 700.

AUXILIARY HEATING

As the building is centrally heated from a plant which is out of operation from mid-May to mid-September, and, in order to provide against abnormally cold weather at any time of the year, electric fires are installed in all wards and in the sitting rooms, dining room, waiting rooms, consulting rooms and clinics. These are mostly of the built-in type, 3-kW loading in the large wards and 2-kW in the small wards. It is usually found that 2 kW will quickly raise the temperature to, and 1 kW maintain it at, the necessary comfort point.

The auxiliary heating in the operating theatre does not follow the same lines as that in the wards and other accommodation. On account of the danger of ignition or explosion of ether vapour, the radiators are of the convection type. The socket-outlets are interlocked with mercury switches for portable radiators, and, whether the radiators are portable or built-in, no open-type switches are used.

SIGNALS

Complete systems of communication are essential. At each bed, grouped with the lighting switch and socket-outlet, there is a push button and, in addition, a socket-outlet which allows for the occasional connection of a flexible lead and pear push for the use of those patients who are unable to reach the ordinary push. Outside the door of each ward is a luminous signal with reset button, and in each ward kitchen a luminous-type indicator and buzzer. When a push button is pressed, the door signal shows a red light and simultaneously the appropriate lamp on the indicator glows, indicating to the nurse on duty the wing or corridor to which she must proceed in order to deal with the call.

Subsidiary bell systems deal with calls from entrance doors, dining room, waiting rooms, etc., which are received on an indicator of pendulum pattern located in the kitchen corridor.

All systems are entirely independent up to a distribution board from which they take their supply, to provide isolation and to facilitate the location of a fault. Current is obtained from a 12-volt 100-watt transformer and, as a standby, through a 2-way switch from five cells of the emergency lighting battery.

The internal system of telephones is automatic. In this case, where the hospital block is one of a group of buildings, all telephones are operated through one central automatic exchange in order to provide complete intercommunication. Instruments are installed in each ward kitchen, in the main kitchen and in the physicians' and surgeons' retiring rooms. In addition, each ward corridor has, opening off it, a small room where a telephone conversation may be conducted in strict privacy.

Post Office telephones are included, which consist of a switchboard wired to plug connections in those single-bed wards intended for occupation by private patients. Thus a patient can get into communication with office, home or friends. A number of portable sets are kept, ready for issue. Further telephones for staff use have direct lines to the public exchange, so that it is unnecessary to employ a special operator for the hospital board.

BROADCAST RECEPTION

At each bed-head, and grouped on the same plate as the light switches, hand-lamp socket and bell push, there is a socket for plugging in a headphone. All these are wired through distributing boxes to a receiving set located in the waiting room. Further headphone sockets are located in various staff rooms, and a loud-speaker in the dining room.

SPACE HEATING

As electricity is available at a low rate only during off-peak periods, heat storage is provided by raising the temperature of a large volume of water contained in a suitable closed tank. The heating of the hospital, therefore, is carried out by means of low-pressure hot water. The various circulations are sub-divided through isolating valves at headers in the heating chamber. All risers are carried to roof level, whence they spread horizontally throughout the building. From the roof space drop-pipes in channels arranged in the walls serve panel-type flush radiators, arranged as far as possible below windows.

Heat requirements are carefully calculated for each room, and the sum represents the hourly dissipation of heat during those hours in which low-tariff-rate electricity is not available. A simple calculation gives the volume of water required—in this example, 2 000 gallons ranging in temperature from 220° down to 140° F. The capacity of the heaters is such that they raise the temperature of 2 000 gallons by 80 deg. F. during the off-peak period whilst at the same time making good the heat losses of the building. Added to this duty is the provision of about 1 500 gallons of washing water per day at a temperature of 120°–130° F. Two 200-kW electrode heaters meet these requirements.

Briefly described, a 400-volt 3-phase supply is taken independently from the substation through isolating switches to two automatically-operated oil-immersed switches, one for each heater. Also, from the isolating-switch panel an anxiliary supply is carried to a distribution fuse-board for the circulating pumps and to the relay control panel.

The maximum loading (up to 200 kW) per heater can be preset on the panel and, on turning on a tumbler-switch, the operation of the plant is entirely automatic. In sequence the primary circulation pump starts up, the electrode shields in the heaters move to their low-load position and one or both of the automatic switches close, putting the plant on load, which rises gradually to the value of the presetting. When the temperature of the water in the storage tank has risen to the required value a thermostatically-operated relay opens the main oil switches and leaves the plant ready for the next cycle of operations. Full protection is arranged against overload and earth-leakage faults.

The hot water from the heat-storage tank passes through an automatic valve which mixes it with some of the cooled water from the heating system and maintains it at a

preset value of 150° to 180° F. according to weather conditions.

COOKING EQUIPMENT

To cater for the needs of patients and staff, the cooking and other appliances listed in Table 1 are installed.

Table 1

Appliance	Loading
3-oven range with 12 boiling-plates ..	40 kW
15 in. × 12 in. × 8 in. griller and toaster	3 kW
7 ft. × 2 ft. 6 in. boiling-plate and hot closet	7·5 kW
Two 15-gal. capacity boiling pans, together	15 kW
Two 18 in. × 24 in. × 24 in. steaming ovens, together	16 kW
Dish-washer, capacity 3 000 pieces per hour, with hot-rinse boiler	7·5 kW
Mixer and mincer	1·0 h.p.
14-lb. capacity potato-peeler	0·5 h.p.
Refrigerator, 50 cu. ft. capacity	0·5 h.p.

All the cooking appliances are spaced around the kitchen walls, each with its isolating switch and control panel, on which are mounted 3-heat switches and pilot lamps. The range, griller and steaming ovens are fitted with canopies connected through metal ducts to a vertical flue finishing at roof level in a small extraction fan.

The arrangement of these appliances was carefully considered in relation to the layout of kitchen, scullery and vegetable-preparation room, so as to avoid cross traffic as far as possible and to provide an uninterrupted circulation for soiled dishes and cooking utensils.

Also under "cooking" may be included the 15-ampere switch socket-outlets installed in the ward kitchens for boiling-plates and kettles, though these are supplied from the heating section of the installation and not from the cooking circuit.

X-RAY EQUIPMENT

Deep therapy, violet-ray and other types of electric treatment are provided for elsewhere, and an X-ray outfit is installed for diagnosis only. This consists of a couch with tube and control panel, and a fluorescent screen. The question of the appliances to be installed and their layout is decided according to the ideas and requirements of the specialists and manufacturers, but in any case it is desirable to provide cable capacity for 50 kVA with a fall of potential of not more than 2 volts from the main switchboard.

Associated with the X-ray department is a developing room for films. This is equipped with a special developing ruby lamp, an amber top light and an ordinary light; both the latter are controlled from one 2-way switch in order to lessen the risk of accidentally spoiling a film. Another necessary item, to be provided in the design of the building, is a light lock separating the developing room from the X-ray room, in which it is safer to provide no light whatever. Included in the electrical equipment of the developing room is an immersion heater for warming developer.

STERILIZING

In connection with the operating theatre there is a sterilizing room containing a pair of 5-gal. water sterilizers (5 kW), a bowl sterilizer (5 kW), and an instrument sterilizer (3 kW). All of these are fitted with safety devices to cut off the current should they be allowed to boil dry. They are controlled through isolating switches and, in the case of the bowl and instrument sterilizers, through 3-heat switches. Over the sterilizers is fitted a suitably proportioned canopy connected to a ventilating system. There are also three sets of sterilizers similar to the foregoing installed in utility rooms adjoining the ward kitchens on each upper floor, for the use of the wards.

In addition to the sterilizers referred to above, in a room allocated for the purpose is installed a 4 ft. × 3 ft. × 1 ft. 9 in. sterilizer with capacity for 24 10 in. × 8 in. drums for dressings. This works at a pressure of 30 lb. per sq. in. and is fitted with a vacuum ejector. Steam is raised in a 35-kW electrode boiler with automatically operated feed pump and pressure controller.

LIFTS

Each end of the building is provided with a push-button-controlled lift having a maximum capacity of 10 cwt. at 90 ft. per min. Essentials aimed at were a landing speed of not more than 10–15 ft. per min. and also silence of operation of motor, controller and gates. Gradual and smooth acceleration and deceleration were attained by the use of variable-speed a.c. commutator motors. The power requirements are 6–7 h.p. per lift.

VENTILATION

In general, natural ventilation is adopted, but special ventilation is provided for removing odours from the kitchen, fumes from the operating theatre and steam from the sterilizer room. Vertical shafts are provided up to roof level where exhaust fans are installed in hutches built for the purpose, the controls being located in the appropriate rooms. One fan serves the kitchen and one takes care of the operating theatre and the sterilizer room. The power loading of each of these fans does not exceed 1 h.p.

WIRING INSTALLATION

The estimated maximum loading of the entire installation is as shown in Table 2. A further application of diversity brings the simultaneous maximum loading down to about 600 kW. The X-ray installation is not taken into account, as the loading at the higher values is momentary only.

Table 2

	Connected	With diversity
	kW	kW
Lighting	32	30
Auxiliary heating	477	190
Power, 6 motors	17	8
Sterilizers	100	48
Kitchen appliances	93	60
Electrode heaters	400	400
Total	1 119 kW	736 kW

The general scheme of main connections is as follows: On the consumer's side of the supply authority's substation there are four 350-ampere oil-immersed triple-pole and neutral circuit-breakers fed from a common busbar chamber. These circuit-breakers with their 4-core paper-insulated cables are arranged in pairs, one pair for the electrode heaters and the second pair for general purposes. Thus, in the event of damage to or breakdown of one cable, the other will keep the hospital in commission without serious inconvenience, isolating switches being provided for this eventuality both in the heating chamber and at the general-purposes board.

The general-purposes switchboard is an iron-cased unit having two 400-ampere triple-pole and neutral incoming isolating switches, a busbar chamber and an instrument panel. Mounted over and under the busbar chamber are four 200-ampere double-pole switch-fuses for heating circuits, three 100-ampere for lighting circuits, one 200-ampere for the cooking circuit, one 200-ampere for the X-ray circuits, two 60-ampere (triple-pole) for lifts and one 60-ampere (triple-pole) for other power purposes.

The cooking switchboard is located in a room adjoining the kitchen and is similar in type and arrangement to the main general-purposes board, except for the addition of a watt-hour meter. It has three 100-ampere and seven 60-ampere double-pole outgoing switch-fuses controlling the circuits to the cooking appliances.

From the switch-fuses on the general-purposes board, mains are run to main distribution fuse-boards and sub-mains thence to sub-distribution fuse-boards, from which the various lighting, heating and power sub-circuits are carried to their respective outlet points.

INSTALLATION WORK

Mains from the general-purposes switchboard to main distribution fuse-boards are paper-insulated, lead-covered and single-wire-armoured. All other wiring is run in galvanized-steel conduit concealed in the concrete of floors and under the plaster of walls. Conduits are laid before concreting is started and are so arranged as to provide, through the medium of outlets and specially provided draw-in points, for wiring after all conduit work has been completed. All joints in conduits are carefully made watertight with red lead and are well tightened to ensure electrical continuity.

Wires and cables for lighting, heating and power circuits are rubber-insulated, 660-volt grade (C.M.A.). They are drawn in after the conduit has been erected and the plastering of walls completed. All cut ends are carefully sealed as wiring progresses, in order to prevent moisture penetrating the strands of the conductors and lowering the insulation resistance.

The wiring of bell and call signalling systems is carried out in 1/·044-sq. in. and 1/·036-sq. in. rubber-insulated and braided wire in galvanized conduits, erected at the same time as the wiring for lighting, etc. Each indicator system is complete in itself and all obtain low-voltage current for their operation through a distribution fuse-board. This arrangement enables a defective system to be isolated until the fault has been traced and repaired, and at the same time protects the transformer or battery, as the case may be.

The automatic telephone installation is wired with 3/·020-sq. in. electrolier wire twisted in pairs and run in galvanized conduit from instruments to a junction box in a central position in the basement, where they join to a multi-core lead-covered cable which connects with the automatic exchange serving this and other buildings under the same administration.

Faults to earth are dealt with by relays on the control panel of the electrode heaters and by the overload trips on the oil switches in the substation. The general wiring of the building, on the other hand, relies entirely for protection upon fuses and the careful and effective bonding and final earthing of conduits and main switchboard. No other choice presents itself, as conduits laid when the concreting of the floor is proceeding cannot fail to make casual contact with the steel reinforcement, thus providing a path to earth via the steel frame of the building and rendering earth-leakage trips ineffectual.

OUTLAY

Although capital costs may vary considerably according to the degree of compactness of a building, it may prove of interest and use to know what the equipment of a hospital block such as the one under review costs in relation to its volume. The figures given in Table 3 relate to the level of prices obtaining in 1938.

Table 3

	Pence per cu. ft.
Mains, fittings and wiring for all purposes	2·20
Space heating, including electrode heaters, tanks, pipework and radiators	1·80
Lifts, excluding grilles or enclosures ..	0·83
Kitchen appliances and their controls ..	0·60
Water, bowl, instrument and dressings sterilizers	0·62
Total	6·05

CONCLUSION

If omissions are to be avoided and the best results obtained as regards completeness, appearance and accessibility, an immense amount of careful planning is essential, all of which should be completed before building work starts. It is seen, therefore, that the closest co-operation is necessary between the hospital authorities, the architect and the engineer; the hospital authorities to ensure that they are getting what they require and that they fully understand what they are getting; the architect to enable him to provide suitable basement and vertical ducts, reasonable lift machine-rooms, and to obtain from him detailed information revealing the location of lockers, tables, beds, lavatory basins, the hinging of doors, etc. For his part, the engineer helps by cutting down to a minimum the alterations and additions so frequently found necessary in carrying after-thoughts into effect. He can also indicate where holes may be left in floors and walls during the progress of building operations, and so save a lot of expensive and unnecessary hacking-up of finished work.

SHEFFIELD SUB-CENTRE: CHAIRMAN'S ADDRESS

By F. C. CLARKE, B.Sc., Associate Member.*

"TRAINING OF ELECTRICAL ENGINEERS"

(ABSTRACT *of Address delivered at* SHEFFIELD, 16*th October*, 1940.)

May I begin by stating in no formal manner the honour which I feel at being asked to be your Chairman. When I accepted the office of Vice-Chairman 2 years ago, I little thought that I should be giving my Chairman's Address at about 4 p.m. in order that my audience of electrical engineers, containing many lighting experts, might get home before dark. I am also a member of an engineering society which meets near here and chooses the nearest Friday to full moon at 6.30 p.m. for its meetings. Thus, in a topsy-turvy world, we have reverted to the ways of our forefathers. But we live in hope of a better world where saner ways of living and doing things will be the accepted code.

The present outlook, together with my own interest in the training and education of young engineers, prompted me to examine some of the opinions expressed by various speakers and recorded in the *Journal* on the subject of the recruitment, training and status of the electrical engineer. I felt that we should consider how far those hopes and aspirations had materialized, and what modifications of those schemes should now be considered desirable in view of our present experiences and the urge to plan for the days of peace after victory.

Planning must be based on ideals, whatever the cynics and pessimists may say, recognizing that human frailty only permits an approximation to those ideals and a result which is the greatest common measure of the considered opinion of those responsible for the planning.

I should like to feel that the Council of The Institution would see the importance of giving serious consideration to the formation of a special committee whose terms of reference would be to report on the recruitment and training of all entrants to the electrical industries and to the profession of electrical engineer, and on the standards that should be aimed at in the qualifications of those responsible for manufacture, design, craftsmanship and the generation and distribution and commercial and economic utilization of electricity.

In previous surveys of this problem we have started with the assumptions that there are three types of educational institutions from which entrants are drawn: (1) elementary schools, (2) secondary (including public) schools, (3) universities.

Among the mistakes made by those who produce schemes of training are the following: (1) They ignore the full-time work of the technical schools, both junior and senior. (2) They class the junior technical school with the elementary school, a very great mistake. (3) They speak of a "good general education" without defining it or analysing its content.† (4) They assume that the curricula in all secondary schools include physics (which is far from being the case), and that the inclusion of the subject "physics" in the list of subjects on a School Certificate indicates a knowledge of mechanics and electricity. (5) They do not appreciate the difference between School Certificate and Matriculation.

One often hears of a firm seeking a "gentlemanly youth who has matriculated." Unless the firm wishes the youth to proceed to a London University external degree by working in his spare time, or is prepared to release him at some time for a few years' work at a resident university, matriculation is purposeless.

It may be explained in passing that a junior technical school is recruited by examination (usually competitive) amongst children from elementary schools from the ages of 12 + to 13 +, who then follow a curriculum for 2 or 3 years which covers, with general subjects, physics (including mechanics and electricity), chemistry, engineering drawing and workshop practice. The result is a "good general education" in the modern sense. The only handicap, though not a drawback, is that these boys do not prepare for a recognized examination of a national type or conducted under the aegis of a university.

Senior full-time courses in technical colleges are not so widespread. Such courses would undoubtedly be more appreciated if their aims were better understood. There would then be a demand for their multiplication. They are planned to give a youth of School Certificate standard a curriculum of study and practical experience, and to prepare him to enter industry with a view to occupying a minor post of responsibility, demanding a background of scientific knowledge and training appropriate to the industry he is entering. Such a youth rapidly develops an intelligent grasp of the work he is required to do and of the responsibility attaching to it.

The subjects of study are mathematics, physics, applied electricity, heat engines, mechanics and strength and properties of materials, metallurgy and engineering drawing with Workshop Practice; and at least 60 % of the time is spent in laboratories, workshops and the drawing office. Further, the teachers—the full-time staff of the technical college—are nearly all men with some years of industrial and often research experience who hold high university degrees in science and technology.

In this connection I would refer again to the Spens Report,† which was drawn up by the Consultative Committee of the Board of Education after 5 years' investigation of a problem of particular interest to this Institution. Their terms of reference were "to consider and report upon the organization and inter-relation of schools, other than those administered under the Elementary Code, which provide education for pupils beyond the age of 11 +;

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† See Appendix II, p. 403, of the Spens Report ("Secondary Education, with Special Reference to Grammar Schools and Technical High Schools," 1939, H.M. Stationery Office); also A. N. WHITEHEAD: "The Aims of Education" (1929), p. 74.

† *Loc. cit.*

regard being had in particular to the framework and content of the education of pupils who do not remain at school beyond the age of about 16."

But for the war the Spens Report would be one of the burning questions of the day, and I hope that after the war its recommendations will be carried out. There will then be an occasion to make a further inquiry into the education and training to be followed by our youth after the age of 16 years.

The Report envisages the establishment of three types of secondary schools: (1) modern schools, which are to be an extension of the existing "central" type of schools; (2) grammar schools, which will be much on the lines of the existing secondary and grammar schools; and (3) technical high schools, an extension and development of what are now known as junior technical schools.

As all these types of secondary schools will be attended by children of ages from 11 + to 16 +, and in some cases by children over that age, it is from them that the engineering profession and industry will draw the great majority of its recruits. It is therefore of paramount importance that The Institution of Electrical Engineers, and indeed all the professional institutions, should give their closest study to this Report.

The third type of secondary school—the technical high school—represents the most revolutionary departure from existing practice and is naturally the one which most concerns those responsible for the scientific industries of the country.

What does the Report say of technical high schools? I will quote from the summary of principal conclusions, suggestions and recommendations.

Technical High Schools.

"We are convinced that it is of great importance to establish a new type of higher school of technical character quite distinct from the traditional academic Grammar School. As a first step to this end, we recommend that a number of existing Junior Technical Schools orientated towards the engineering and building industries, and any other Technical Schools which may develop training of such a character as (*a*) to provide a good intellectual discipline altogether apart from its technical value, and (*b*) to have a technical value in relation not to one particular occupation but to a group of occupations, should be converted into Technical High Schools, in the sense that they should be accorded in every respect equality of status with schools of the grammar school type. We recommend that such schools, which would recruit their pupils at the age of 11 plus and provide a five-year course up to the age of 16 plus, should be called Technical High Schools to distinguish them from the full-time Technical Schools of other types which provide courses for pupils beginning at the age of 13 or 14."

"The curriculum for pupils between the ages of 11 plus and 13 plus in Technical High Schools should be broadly of the same character as the curriculum in other types of secondary school of equal status."

"For pupils above the age of 13 the curriculum should be designed so as to provide a liberal education with Science and its applications as the core and inspiration. The subject matter would be English, History, Geography, Mathematics, Science, Engineering Drawing, Practical Crafts in the workshops, Physical Education and the Aesthetic Subjects, together with continued study of a foreign language for those pupils who have shewn that they are capable of profiting by it."

"We strongly recommend that, wherever possible, Technical High Schools should be housed in the premises of Technical Colleges or Technical Institutes. In cases where it is not possible to accommodate the Technical High School in a Technical College, we think that it is most desirable that its buildings should be linked with the College buildings in order to facilitate full use of the equipment and staff of the college."

"We recommend that a new type of leaving certificate should be established for pupils in Technical High Schools on the basis of internal examinations founded on the school curriculum, and subject to external assessment by assessors appointed or approved by the Board of Education in order to afford an adequate guarantee for a uniform minimum standard of certification in Technical High Schools throughout the country: We recommend that the arrangements for this leaving certificate should be planned on lines similar to those in use for the existing examinations for National Certificates."

"We recommend that these certificates should be given an equal standing with School Certificates as fulfilling the first condition for matriculation."

"We hope that employers and Trade Unions will see their way to reconsider the conditions of entry into and service in industry, with special reference to the age of admission and the period of apprenticeship required for boys who have taken a course in a Technical High School."

"We are strongly of the opinion that there is room for a considerable development of Technical High Schools; and we suggest that the provision of Technical High Schools in association with Technical Colleges does not concern exclusively the more highly industrialised areas. We commend this problem to local authorities for their careful consideration."

I trust that The Institution of Electrical Engineers will see its way to give the Technical High School its unqualified support.

It is appropriate here to draw attention to matters regarding which the electrical industry, in common with all engineering industries, should make up its mind what it wants and what it expects the schools to produce.

Industry, when seeking its recruits, asks for youths of certain ages for the particular vacancies that have to be filled. The following points should be borne in mind: (1) That there are no boys of 14 years available who have had practical workshop experience at school. The small amount of manual training a boy of this age has had, usually in wood, is very little guide to his future capacity as a craftsman. Yet it is at the age of 14 that boys whom the employer intends shall become craftsmen are usually engaged.

(2) That a youth of 16 years who holds a School Certificate will not have had any technical training unless he is the product of a junior technical school (though the acceptance of the finding of the Spens Report will overcome this difficulty).

Industrialists seeking "a well-educated youth" will have to place the age of entry at 18 + as a minimum, and that should be the age of entry of the school apprentice; but I hope that in the future there will be less insistence on a maximum age of entry. Some youths take a considerable time to decide what they want to be.

The "college apprentice," i.e. the man who has obtained a university degree or its equivalent before entering the engineering profession, undoubtedly fills a definite niche where research work is required; but it is a question worth investigating whether a "School apprentice" of the kind I have described, i.e. a boy with a School Certificate who has had 1–2 years' training in a technical college, would not prove better qualified to fill a junior executive post.

Such an apprentice is an economic asset from the day he enters the firm. He is quite capable of testing and inspection work of progressive difficulty, and can do the work of a junior draughtsman. He is adaptable, and not expensive. He is fairly modest and anxious to learn and find his way about the works. There will, however, have to be some adjustment of the age of calling-up of such men for military training.

A further class of youth who is often required is only provided in very limited quantity; I mean the youth who is wanted to fill posts on the costing or commercial side of industry. A certain amount of technical education is necessary here, together with some commercial or statistical training. It is curious that the study of industrial administration and workshop organization seem to be mainly offered in technical colleges. These subjects should preferably be studied by those who have had some industrial or workshop experience, and the question of releasing senior school apprentices in the daytime for study of this sort should receive consideration.

I should like in conclusion to say a few words about the human factor. We all want our workshops and offices to be happy places, where good work is done each day. The foundation of this should be honest rivalry in getting a good name for the firm and its output. Every position should offer opportunities for advancement to the youth who is ambitious and is prepared to work to improve his knowledge and skill. I suggest that a simple reward and recognition of good work should be the release for study at the local technical college on 1 or 2 half-days per week. It takes the pressure off the evenings, when a youth is entitled to relax and enjoy the society of his friends or the cinema or a dance, instead of (in many cases) hard work in the daytime for 48 hours per week, 3 or 4 evenings per week in classes at the technical college, and the remaining evenings doing homework or supplementing the all too inadequate time which his lecturers can give to his subjects.

The study of social or cultural subjects is pushed quite into the background by this devotion to business and to technical studies, often amounting in total to 60 hours per week, with serious loss to the social qualifications of executive personnel. A single game of football on Saturday afternoon, without any physical training, puts too big a strain on these youths and in the case of the most zealous students often produces a rather one-sided young man who becomes a bit sour when his employer, looking around for someone to fill a vacancy, passes him over because of his unattractive personality. The employer probably gives the job to a more pleasing but less tired youth, and so produces another disgruntled employee, who either throws up his studies in disgust and despair or tries to get another post. These hard-working, studious youths want looking after and directing. They often overdo this study business.

I should like, at the risk of being charged with uttering platitudes, to draw attention to certain fundamentals which are often overlooked: (1) There will always be criticism of the ability of the lower-paid workers; the economic opportunities of any industry will always sift out the more able and ambitious youths from the lower ranks. (2) Employment, especially in a scientific industry, should always offer a career of progress and advancement. (3) With the present system of education and selection the cream of our youth goes to the secondary school. (4) Training should be made a statutory requirement, since otherwise only the conscientious firms carry the burden of training.

In conclusion, I would advise those who are interested in this question to study the mass of collected experience and opinions to be found in earlier issues of the *Journal*. I would particularly commend Dr. Fleming's Inaugural Address* and the discussion on "Electrical Engineering Education"† which took place in 1937. Something organized and definite must be done about this question of the recruitment and training of electrical engineers.

* *Journal I.E.E.*, 1939, **84**, p. 1.

† *Ibid.*, 1939, **84**, p. 161.

WEST WALES (SWANSEA) SUB-CENTRE: CHAIRMAN'S ADDRESS

By T. H. DAVIES, Associate Member.*

"HIGH-VOLTAGE DISTRIBUTION AND FAULT EFFECTS"

(*Address delivered at* SWANSEA, 26*th October*, 1940.)

(1) INTRODUCTION

I propose to consider in rather a general way some of the interesting points which transmission engineers have to deal with when preserving continuity of supply. Not unnaturally, some of my remarks are drawn from my own experience gained from the system with which I am connected. This is a composite one, made up of overhead and underground networks of various voltages up to 33 kV, working on the principle of neutrals earthed through limiting resistors.

The subject of continuity of supply is vast, important, and was never more vital to the national war effort than at this moment, and I feel sure that you will agree with me when I say that a great deal depends upon our efforts in the supply industry to-day. Undoubtedly the part of any supply system which is the most vulnerable to fault hazards is the distribution side, since power-station faults are becoming rarer with improvements in the design of equipment. The composite system is more susceptible to faults and more difficult to safeguard and protect against them than a wholly underground or wholly overhead system; at least, that is my experience.

(2) SURGE EFFECTS

My remarks are concerned with the more common type of fault. The transmission-line surge offers a wide field for research, but supply engineers are more concerned with the effects of the surge than with its make-up. Surges can generally be recognized as due to one or more of the following causes: switching operations, insulator failures, cable faults, birds, lightning, outside sources. I should like to say a few words about the salient features of each of these causes as they occur to me, and also to make some remarks on the safeguarding and the testing of protective gear in connection with them.

(2.1) Surges due to Switching Operations

Switching surges vary according to whether the switching is carried out under light or normal load, or under fault conditions. In any case, they can be classed as normal-voltage hazards, and the constants of the system will have some bearing on their prevalence; the surge impedance of the system will be an indication of this.

Composite systems are generally not without a number of transition points, and it is at these places that over-voltages are magnified as a result of changes in circuit impedance. Flash-over may take place at such points, which are generally cable sealing-end boxes, where they are least wanted. However, switching surges on any system can be reduced by using orthodox switching methods, whether under normal or abnormal conditions.

(2.2) Surges due to Insulator Failures

The design of insulators is such that a high degree of reliability is given on high-voltage distribution overhead lines. Apart from the many factors which influence their design, there is one of special interest at the moment in connection with overhead lines near coastal districts. I refer to those insulators which have to take industrial pollution as well as salt deposits. It is to be hoped that an insulator design suitable for meeting this hazard will be evolved in the near future.

There is often no alternative but to over-insulate as a means of overcoming the deposit condition, and as a result of this the proper co-ordination of insulation levels throughout the system becomes slightly difficult. There is the danger of throwing back any surge over and above the minimum flashover value of the line to substation or even station switchgear, with consequent damage to current transformers, etc. Weak links are sometimes used at vantage points, but unfortunately allowing a flashover means putting up with an interruption to supply—on single feeders, of course.

(2.3) Surges due to Cable Faults

The percentage of surges due to cable faults on any system should be comparatively small. Surges of a transient nature may be set up in the early stages of the development of a fault, and, generally speaking, complete breakdown will occur very soon afterwards unless steps are taken to break down the fault by the over-voltage test and so locate the fault before any real damage is done. This is now more or less an established practice with most undertakings.

(2.4) Surges due to Birds

These are mostly of a transient nature, and intelligent safeguarding at vulnerable points will reduce them appreciably. Where new lines are being constructed the safeguards can be embodied in the design; for instance, the herringbone type of bracket is particularly successful. But some types of construction demand more attention than others. Such places as duplication points, angle poles, tappings, road crossings and transition points will always be vulnerable. 6-wire lines, using horizontal metal cross-arms, and running through wooded country, ploughed fields, or near refuse dumps, nearly always claim special attention from birds.

* The Llanelly and District Electric Supply Company, Ltd.

The success of protection against birds depends upon the type of guard chosen and upon where it is fitted. It should at least possess the following qualities: high insulation, low cost, resistance to atmospheric conditions, easy application. There are three main types of guards which satisfy these requirements—the earthenware, the fibrous and the plastic mould. The earthenware one must fit closely over the channel arm, the fibrous ones are easily fitted, while the plastic type is more streamlined but takes longer to fit. The use of the long spindle can be advantageous, but even this does not eliminate the possibility of flashover between line wire and earth. My experience is that birds do not always alight in the obvious places.

Digressing for a moment, it is interesting to note that a number of supply authorities are experiencing attacks on their wood-pole lines by the woodpecker. Unfortunately the woodpecker is a protected species and the damage will therefore tend to increase with time, necessitating pole replacements, which are a nuisance, apart from the cost and inconvenience to consumers. It appears that poles are rarely attacked below 10 ft. from ground-level. Numerous remedies have been tried out, such as wood, cement, and bitumastic fillings, and these are generally covered over with galvanized sheeting. These may put a stop to the immediate trouble, but further attacks on the same pole may be expected. A piece of small-mesh wire netting wrapped round the pole down to about 10 ft. from ground-level will prove to be an immediate deterrent which will prevent penetrative attacks until arrangements have been made for changing the pole; this is generally necessary in the end.

These remarks are concerned with poles of Norwegian red fir, and they may be difficult to obtain under the present circumstances. An authority on wood preserving has suggested the use of larch, Scots pine or spruce, which may be preferable because these trees are rarely attacked by woodpeckers.

(2.5) Surges due to Lightning

The protection of overhead lines against lightning surges has always been a bone of contention with transmission engineers. Up to the year 1930 there was not an efficient and reliable piece of lightning protection apparatus on the market, and those in existence generally gave more trouble in themselves than protection against lightning. The extensive use of earth wires had to be relied upon; later the earth wire went out of favour, chiefly because inefficient clamping-in devices and "make-offs" were being used. Nowadays it is general practice to have the same factor of safety for the continuous earth wire as for a phase wire. Complementary to the use of an earth wire is the all-important question of obtaining low footing resistances, but this is a problem in itself. It is useful to lay any extra tubes or earth bonding wire in extended formation immediately underneath the line.

The adoption of cable lengths as a means of protection against surges can only be effective if fairly long lengths are used. The composite system usually has this inherent advantage. Earlier forms of apparatus were the oxide-film and the horn-gap arresters, and then came the auto-valve, the principle of which is used in the more recent designs of arresters. Earlier types of auto-valve gave a lot of trouble, chiefly because designers failed to realize that they had to be efficiently sealed against the weather. As a result of this there was wide dissatisfaction among engineers regarding the auto-valve, and most of them were taken out of service. Subsequently manufacturers had some difficulty in re-establishing confidence in later systems of lightning protection.

Lightning introduces effects on a system which must be dealt with separately, and as long as any system, susceptible to lightning surges, remains unprotected from them outages are inevitable and are very often attended with damage to insulators and switchgear.

There are three modern types of arresters which are fairly successful in practice, apart from earth wires and cables; they are the multi-gap, the absorber and the expulsion gap. The expulsion gap is fitted as a shunt to each line insulator and consists of a fibre tube with one end closed and the other open; the internal flashover voltage is less than that of the string of insulators it has to protect. The disadvantage of this type is that a follow-on power arc might rupture the whole thing, if the rating were insufficient; moreover, frequent operation might give a lessening in the quality of surge dissipation.

An efficient arrester must have an extremely rapid operating time because it has to deal with steep wave-fronts. The material used in the construction of the multi-gap arrester varies with the third or fourth power of the voltage applied, and the time of discharge is practically negligible. Without making a critical comparison between the multi-gap arrester and the absorber it will be sufficient for me to say that both types have their advantages and disadvantages; the essential difference between them is that the arrester is shunt-connected to the line whereas the absorber is connected in series with the line. The function of the arrester is to reduce the peak of the wave and that of the absorber to flatten out the steepness of the wave front of the surge.

Before deciding on which type to use one must satisfy oneself on several points, such as cost, reliability and adaptability. Both types have had widespread use and their reliability has been slowly established. It has been proved that multi-gap arresters, effectively placed, with low earth values, definitely reduce the number of surges and outages due to lightning. The correct positioning of arresters will largely depend upon operating experience, and if records are kept of all disturbances there should be no real difficulty in deciding where to put them. Lack of concrete evidence of the operation of the arresters has always been deplored. One could not make sure that they were doing their job except by waiting over long periods and comparing previous experience. It is now possible by the aid of the discharge-counter* to indicate the actual number of operations of the arresters. The discharge-counter is connected in the earth lead of each arrester or of each set of arresters. Since discharge to earth is so rapid it is impracticable to operate a counter mechanism directly. The discharge is used to discharge a small condenser, which is subsequently charged up from a dry battery, and it is this action which is used for operating the counter mechanism. One counter per set of three arresters is usual, and it is placed near ground-level for ease of inspection. On one particular 33-kV line the counters operated on 85 occasions over a period of 2 years.

* P. F. Stritzl: "The Protection of Electric Plants" (Pitman, 1936).

(2.6) Surges due to Outside Sources

These are surges which occur on other adjacent systems which are linked together, and are transmitted from, say, System A to System B and vice versa. Consider three high-voltage systems linked together by the Grid or some other substantial tie, each system being supplied from its own source of power. Surges of a severe nature may be transmitted and felt in one system or another, thereby affecting plant either synchronously or by low voltage. Some results observed over a period of 5 years on three such systems, linked as described and shown in Fig. 1,

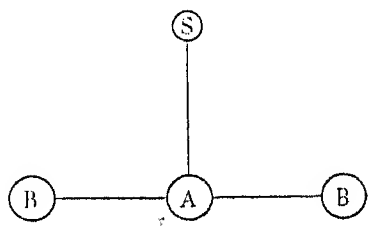

Fig. 1

will now be given. The figures relate to the effect upon an important consumer's substation (S) fed at a distance from A.

Percentage of surges felt at A due to disturbances at A, 62.
Percentage of surges felt at A due to disturbances at B, 38.
Percentage of surges felt at S due to disturbances at A, 26.
Percentage of surges felt at S due to disturbances at B, 12.
Percentage of surges felt at A due to unknown causes, 32.
Percentage of outages at S due to disturbances at A, 18.
Percentage of outages at S due to disturbances at B, 3.
Percentage of outages at S due to causes unknown, 6.

It will be noticed that only 38 % of the total number of surges are actually felt at S due to disturbances at A and B, but the percentage of outages is 21 %. Although the proportion of surges due to B at S is as low as 3 % it must be remembered that the effect on one substation only is being considered, and that what applies to S will apply to many others. Approximately 30 % of the recorded surges at A would also be felt at B, and therefore the surge effect can be said to be reciprocal. It may be argued, however, that the stability of one system or the other might be at fault, and there may be something in this, because prevailing conditions count for much when one is considering surges. However, one must remember that the Grid may be involved, and it has been claimed by high authority that the Grid should not be regarded as a simple transmission system transferring blocks of power from one point to another, but rather as an extended busbar system, and therefore enjoying the resultant characteristic of high stability; but the same thing can be said of any large system as long as conditions remain normal. It may be that this was the original intention when the Grid was first designed, but for all that it is fundamentally a transmission system and the possibility of surge transference exists. The real test of the stability of any system is its behaviour under short-circuit conditions. If disturbances as far away as Southern England can affect remote parts of the country, then an undesirable feature of linking-up is exposed. The fact that surges beyond the limit of one's own system can be felt elsewhere means that the number of outages in the year can be appreciable, and no doubt the figure if taken nationally would be surprising.

(3) PROTECTION

As long as there is the possibility of faults occurring, protective schemes are necessary. All types of protective schemes are designed to limit the amount of disturbance to any system, either by direct disconnection of the faulty section or by suppression of the fault current, according to the scheme used.

The proving of protective gear when first installed, and as a matter of routine, is very important and should be a special feature of the work of preserving continuity of supply. When testing protective gear it is the general practice to include as far as is possible all the apparatus called upon to function under fault conditions. Proper first commissioning tests and a set plan of maintenance tests have their reward in correct operation of the protective gear in an emergency. The tests will depend upon the type of gear to be tested, but generally they should include the following: (*a*) Insulation resistance and continuity of small wiring (this is a matter of routine). (*b*) Check on current-transformer polarities and ratios (this is usually carried out during the first commissioning tests). (*c*) Adequacy of shunt trip power and mechanical efficiency of the circuit-breaker (this is a matter of routine, and special attention is always paid to the tripping circuit at all times).

There are three basic methods that can be used for proving protective gear under conditions approximating as closely as possible to fault conditions.

Method A is that of injection of current into the secondary circuit corresponding to primary fault currents. Where the primary sides of the current transformers are not accessible, as in the case of compound-filled gear, this method may be used for first commissioning tests; but it is nearly always used for routine tests. Minimum disturbance to small wiring and connections is obtained if the test current is injected into the parallel circuit composed of relay coil and transformer secondary. On some types of relays a split plug is used in the current bridge circuit, and the injected test current in this case is in series with relay and transformer secondary. In this method the current-transformer ratio is not proved and short-circuiting of current-transformer secondary turns is not apparent except by comparison with adjacent current transformers. The apparatus for carrying out such tests can be made fairly small and portable.

Turning to Method B, if large currents at small reduced voltage are injected into the primary of the current transformer the relay can be operated for predetermined calculated times depending upon the current and time setting of the relay. These large currents may approximate to fault currents where the current-transformer ratio is fairly low, say up to 1 000 amp. This test is usually a first commissioning one, because the equipment is heavier and usually requires special transport.

When considering directional and non-directional relays, having inverse definite minimum time characteristics, the times recorded on the time-interval meter can be usefully employed for determining the number of switches that it is possible to use in series. If the operating times are plotted against operating currents for each switch the

discrimination between them can be determined. The stability of healthy sections passing "through" fault currents is ensured by comparison at definite minimum time where the curves are parallel and almost horizontal. These curves are useful when it is desired to change settings and they are also a record of the opening time of any associated oil circuit-breaker. With these types of relays the time is only variable up to approximately 10 times the current setting, and definite minimum time is reached at approximately 20 times the current setting. Difficulty may be experienced in obtaining sufficiently high test currents to reach definite minimum time; this is especially so in the case of wound-primary type current transformers where the equivalent impedance is too high. Where large short-circuit currents might flow, current transformers must have low saturation points. This is important because discrimination is very often based on definite minimum times throughout and on high values of current. When current transformers saturate too soon a point may be reached where further increase in primary current may not result in the corresponding increase in secondary induced current; therefore a relay which has been set for operation at high current values may not function in the time it is set for.

A current transformer should withstand the same short-circuit kVA as that of its associated oil circuit-breaker, and manufacturers are aware of the difficulty in achieving this when low ratios are required.

It is useful to have full knowledge of the short-circuit current values at the protected points on a system, especially where back-up protection is provided, in order to arrive at the correct relay settings.

Method C, namely the staging of artificially-placed faults, should be the natural sequel to the first two methods. After the relays have been set according to plan and tested in the way previously described, then the correct thing to do is to prove their operation by staging artificially placed faults, one at a time, bringing as many relays into operation under conditions approximating as closely as possible to normal running conditions. It is not always possible or convenient, however, to obtain the use of spare machines, busbars or feeders, and this factor will determine whether the fault is staged with the voltage controlled or uncontrolled, whether the tested section is isolated or tied-in to the main system, or whether the whole system is tested.

Precautions should be taken to avoid damage to conductors, etc., at the point of application. Line connection through a falling link operated by a trigger will get over this difficulty for earth faults or short-circuits. If the fault is staged with uncontrolled voltage there is no power arc because the voltage collapses on the incidence of the fault, i.e. when the link falls into position. The behaviour of the relays will be observed at this instant. With the voltage controlled, i.e. with the usual voltage regulators in normal running service, the power arc on earth faults will not be noticeable, but in order to deal with short-circuits a pair of arcing horns are introduced in series with the falling link. A lead fuse is stretched between the nearest points of the horns; this will limit the current to a certain degree. When the link falls into position the fuse melts and the arc is drawn upwards in the usual manner, and finally extinguishes itself. This is an imitation on a smaller scale of the arcing short-circuit in air which is sometimes experienced on overhead lines and which has far more destructive effects than anything else. Flashover has a fault impedance determined by the current/voltage characteristic of the power arc, and this in turn is a function of arc length. It is therefore possible to have a very destructive arc with sufficient resistance introduced into the circuit to prevent immediate disconnection by the protective gear. This will be emphasized by its occurrence near the source of supply where the definite minimum time of clearance is longest.

My experience of short-circuits on overhead lines is that, although they occur less frequently than earth faults, they invariably commence as arcing earths and subsequently develop, mainly on the following lines:—

(*a*) When a fault occurs on a phase wire underneath another phase wire an arcing earth will produce, through intense ionization of the atmosphere, vapours which rise and envelop the wire above it. This phase is already above normal voltage; therefore there is an increased tendency to arc-over, often ending in an arcing short-circuit. Cases have been known where all three phases were involved at the same time, using regulation spacing.

(*b*) A flashover to earthed steelwork having a moderately high earth value causing a back arcover to another phase already at a higher potential by virtue of the fault; this again ends in an arcing short-circuit. Tendency to flashover is always helped considerably by industrial deposit or humid conditions or the presence of both, and the subsequent development into arcing short-circuit is more likely to occur in still air.

Reverting to the test, it is useful to calculate the earth-fault current beforehand and to vary it by the use of a variable resistor, perhaps of the liquid type, the relays being observed under light fault conditions. The great advantage of staging faults with controlled voltage is that proof of stability is given, whether favourable or otherwise.

Of course, there will always be special tests for certain protective schemes, such as the Merz–Price, Solkor, Translay and split-conductor schemes, to name but a few; but, generally, if the three basic methods of testing which have been previously outlined are used, then no matter what the protective system employed one can be reasonably assured of the correct operation of the protective gear.

With increase in plant capacity, higher short-circuit kVA values are inevitable, and it often becomes necessary to review the capacity of switchgear to make and break under the new conditions. The thermal rating of cables is also sometimes questioned, and if the cables are not renewed a fault may cause complete burn-out. In some cases it is possible to bring the existing cables within the safe limits if the times of the relays are reduced even slightly, e.g. 0·5 sec. would be sufficient in many instances. It has been previously mentioned that it is usual to set the relays on the basis of the saturation method, i.e. assuming maximum short-circuit current distributed throughout the system; but if the fault current is known at the protected point (the value is always less than that at the source by virtue of the circuit impedance) then the operating times of the relays can be set for that current and not a current that is unlikely to flow. This is characteristic of the directional and non-directional types of relays.*

Any system which has to rely on long operating times for fault clearance near the source of supply has its

* See J. W. GALLOP and R. H. BOUSFIELD: *Journal I.E.E.*, 1940, 87, p. 113.

protective gear wrong in principle. The nearer the fault to the station the more rapid should be the clearance by the employment of fast-acting relays. Perhaps the ideal system should be protected like that, with good lightning arresters effectively placed. One should not forget the possibilities of the use of Petersen coils and like apparatus; arc suppression is being used in this country increasingly.

Initial shocks are lessened considerably by the use of arc suppression, and therefore surges are reduced. This seems to add to the desirability of the more general application of arc suppression. Experience of interconnection before the advent of the Grid was limited, but now that these things have come to light surely the next move is on the distribution side, apart from other considerations. Much can be done in the way of specifying new switchgear, cables, etc., for insulated-neutral operation, so that when the time arrives not so much will be involved should arc-suppression methods be adopted more generally.

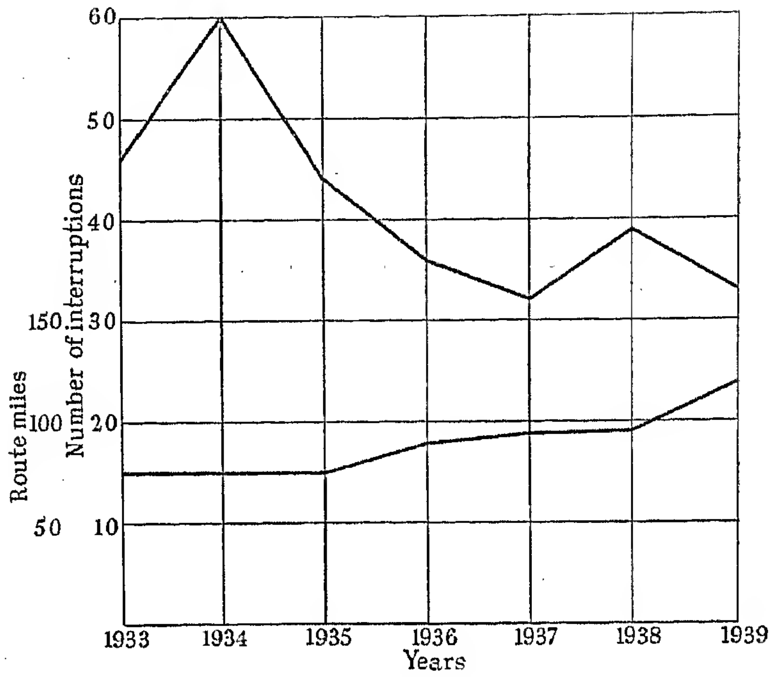

Fig. 2

(4) CONCLUSION

In conclusion, with all this attention to the safeguarding of systems one must naturally expect something in return in the way of reduction of the number of outages. The curves in Fig. 2 give an instance of this. They show the number of interruptions and the route miles of very high-voltage and high-voltage lines, for the period 1933–39. All faults are included; the faults are not confined to those on overhead sections. The greatest number of interruptions occurred in 1934, and as from that year safeguarding was intensified. In 1936, lightning arresters of the latest type were introduced on the various parts of the system. The rise in the number of interruptions shown for 1938 is accounted for by the abnormal number of gales, salt storms and lightning storms during the year. A steady increase in the number of route miles, bringing the total at the end of 1939 to almost double that of 1933, is shown, but the number of interruptions came down appreciably.

The aim of protection and safeguarding is twofold. In the first place, plant and its vulnerable components must be freed from hazards, and secondly continuity of supply must be maintained. Fault hazards should be reduced to a minimum before the protective gear is called into action, and it is only from this angle that success can be guaranteed.

ABSTRACTS OF PAPERS

THE HIGH-RUPTURING-CAPACITY CARTRIDGE FUSE, WITH SPECIAL REFERENCE TO SHORT-CIRCUIT PERFORMANCE

By J. W. GIBSON, M.Eng., Associate Member.*

(ABSTRACT *of a paper which was published in February in Part II of the Journal.*)

INTRODUCTION

The progressive increase in the short-circuit capacity of distributing networks, at both high and medium voltages, has emphasized the necessity of using fusegear of high breaking capabilities and proved performance. The demand has been satisfactorily met by fuses of a number of types, of which the one which has the largest field of use is the filled cartridge fuse. This fuse in its more advanced forms is a reliable piece of apparatus with a precision performance. In essence, it consists of a fuse-element surrounded by an arc-extinguishing filler in the form of a granular non-conducting material, the whole being totally enclosed in a tubular insulating container; the special capabilities of the fuse arise largely from the control of the arc by a solid, instead of a gaseous or liquid, extinguishing agent.

High-rupturing-capacity (H.R.C.) cartridge fuses are now made with breaking capacities such as to permit their use on high-power systems, typical values (3-phase) being 25 MVA at 440 volts, and 300 MVA at 33 kV. Their advantages may be summarized as follows:

(*a*) High breaking capacity.
(*b*) Absence of deterioration.
(*c*) Consistent calibration, leading to—
(*d*) Reliable discrimination with circuit-breakers or other fuses.
(*e*) Cool running.
(*f*) Possibility of low fusing factor (ratio of minimum fusing-current to current rating).
(*g*) Absence of noise and external flame.
(*h*) High speed of operation on short-circuit.
(*i*) Marked current-restricting effect when operating under severe conditions, greatly reducing the deleterious effect of short-circuits.
(*j*) Low value of voltage peak whether operating on overload or on short-circuit.
(*k*) Inverse time/current characteristic is inherent, even even up to very large currents.
(*l*) Low cost.

B.S. No. 88 FOR FUSES

The principal items covered by the above British Standard Specification are (1) current ratings; (2) temperature rise; (3) fusing factor and (4) duty, i.e. breaking capacity. It has not so far proved practicable to standardize dimensions.

The clause dealing with duty standardizes four values of breaking capacity expressed in terms of current, viz. 1 000, 4 000, 16 500 and 33 000 amperes. Because of the current-restricting effect of fuses, short-circuit values are expressed, not as the current which flows through a fuse on test, but as a "prospective current," meaning the current which would flow if the fuse were replaced by a link of negligible impedance.

SHORT-CIRCUIT PERFORMANCE

A suitable solid fuse-filler has a higher arc-extinguishing power not only than air, but also than oil, owing to its property of readily absorbing and cooling metallic vapour from the arc. The resultant hot column of filler and vapour sets up an arc voltage which in practice may be as high as 1 000 volts per inch or more. The effect of the arc voltage in reducing the current to zero may be visualized as the introduction of a steadily increasing resistance in the arc path. Unlike circuit-breakers, the arc voltage is usually high enough to initiate an immediate reduction of current, at whatever point in the voltage wave the arc may commence. Since the action does not depend on the natural passage of the short-circuit current through zero, the fuse has a similar type of performance with direct current as with alternating current. This is in contradistinction to other types of circuit-breaking apparatus, which has a much lower breaking capacity with direct current.

The smaller the cross-section of the element the easier is the duty of the fuse, since the arc contains less metallic vapour to be cooled by the filler. Reduction of cross-section may be obtained in one or more of the following ways:—

(*a*) Low fusing factor.
(*b*) The use of a metal of high electrical conductivity and high melting-point.
(*c*) Increased dissipation of heat from the element. This is inherent in the filled cartridge fuse, on account of the relatively high thermal conductivity of the filler.
(*d*) Sub-division into a number of parallel elements, securing a very appreciable reduction of the total section, on account of the increased surface for dissipation.
(*e*) Increased conduction of heat along the elements from the necks frequently employed, the heating of which determines the fusing current.

A small section of element also results in a very valuable current-restricting effect. If the circuit prospective

* General Electric Company, Ltd.

current is high and the section small, fusion takes place before the prospective current is reached. If at a certain value of prospective current (d.c.), fusion occurs on the initial substantially straight part of the current/time curve, where the slope depends only on the voltage and inductance of the circuit, then, although a reduction of resistance results in an increase of prospective current, the current actually reached is unaltered. This limiting current is inversely proportional to the cube root of the circuit inductance. In the corresponding a.c. case, if short-circuit is initiated on a rising voltage or near a peak of voltage, the rise of current is approximately linear throughout the pre-arcing period, so that again the cut-off current is inversely proportional to the cube root of inductance; if the power factor is low, it is directly proportional to the cube root of the prospective current. Fig. 1 gives a family of curves showing the current-restricting effect on alternating current for selected ratings from a certain range of cartridge fuses having a B.S. No. 88 duty rating of 440AC4.

The arc voltage is substantially independent of the circuit constants and does not vary greatly with current. For a given current, filler, and section and material of element, it increases with the length of the arc. At final clearance the resistance of the arc path builds up as its temperature falls; the fuse voltage therefore reaches the circuit recovery-voltage in a relatively gradual way, the current correspondingly tailing-off to zero. This method of operation as illustrated by the cathode-ray oscillogram of Fig. 2, prevents the setting up of high-frequency voltage oscillations.

The reduction of current may be considered in the light of the following voltage equation:—

Circuit e.m.f. + Inductive voltage + Arc voltage of fuse + Resistance drop in rest of circuit = 0,

in which the first two voltages oppose extinction, and the second two assist. The resistance of the circuit, which if the fuse is quick-acting exerts no influence during the *pre-arcing* period, can now be seen to have its effect during the *arcing* period by increasing the rate of fall of current and thereby reducing the arcing time and so the energy developed in the fuse.

While circuit-breaker performance may be considerably influenced at the zero pause by variations of circuit capacitance and so of natural frequency, there is in general no analogous action in the case of cartridge fuses. It might be expected that the rate of rise of restriking voltage of the circuit would largely determine the rate at which the arc voltage increases at the instant of vaporization, but this is not borne out in practice. Thus a test similar to that of Fig. 2, but with capacitance added to reduce the natural frequency to 1·0 kc./s. and the natural recovery rate to 2·8 V/μsec., showed only a very small change in rate of rise of arc voltage.

Certain fuses are liable to fail on moderate overload by prolonged arcing. Special care must be taken by the

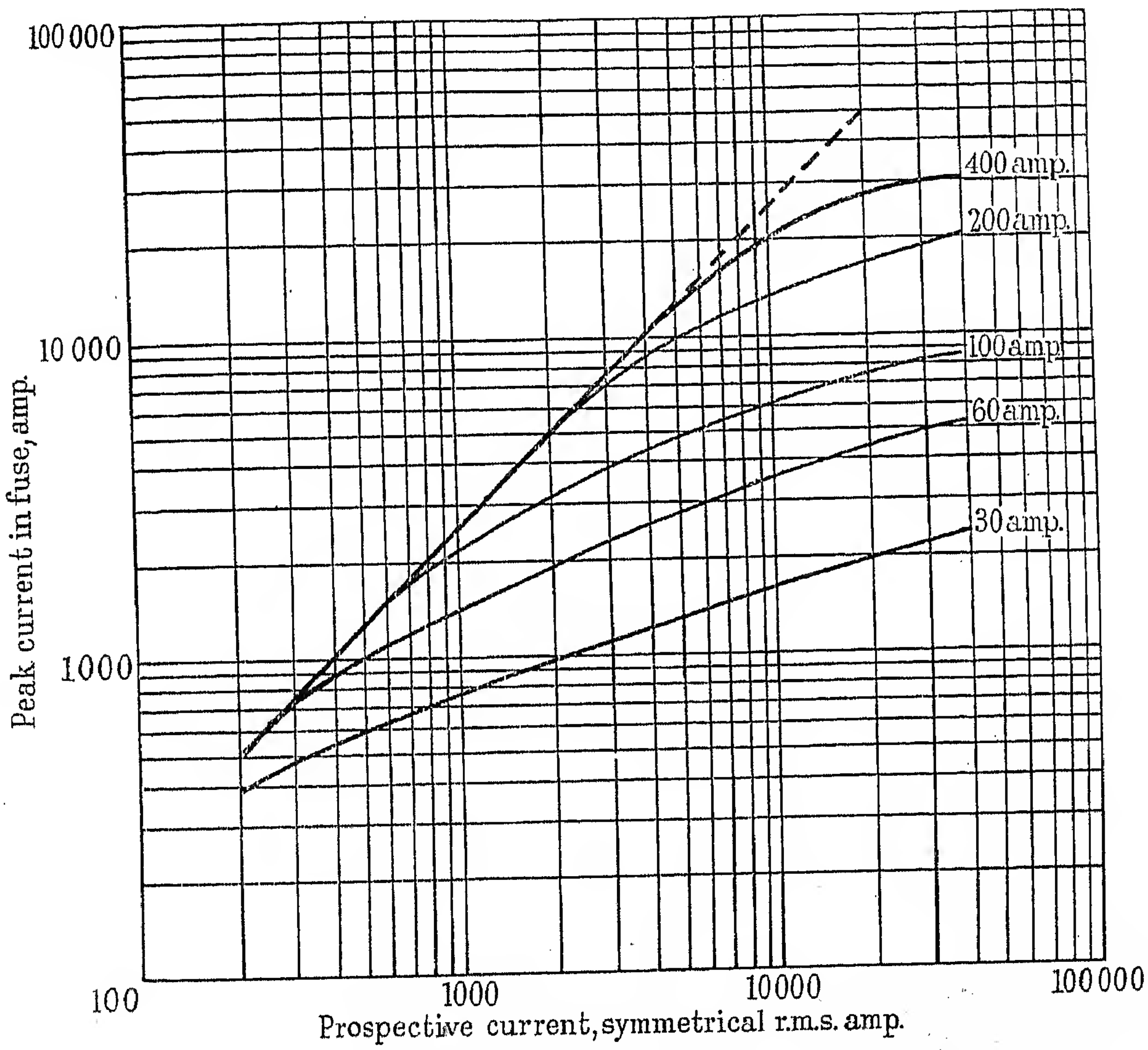

Fig. 1.—Current-restriction curves for cartridge fuses of various sizes. Frequency 50 c./s.

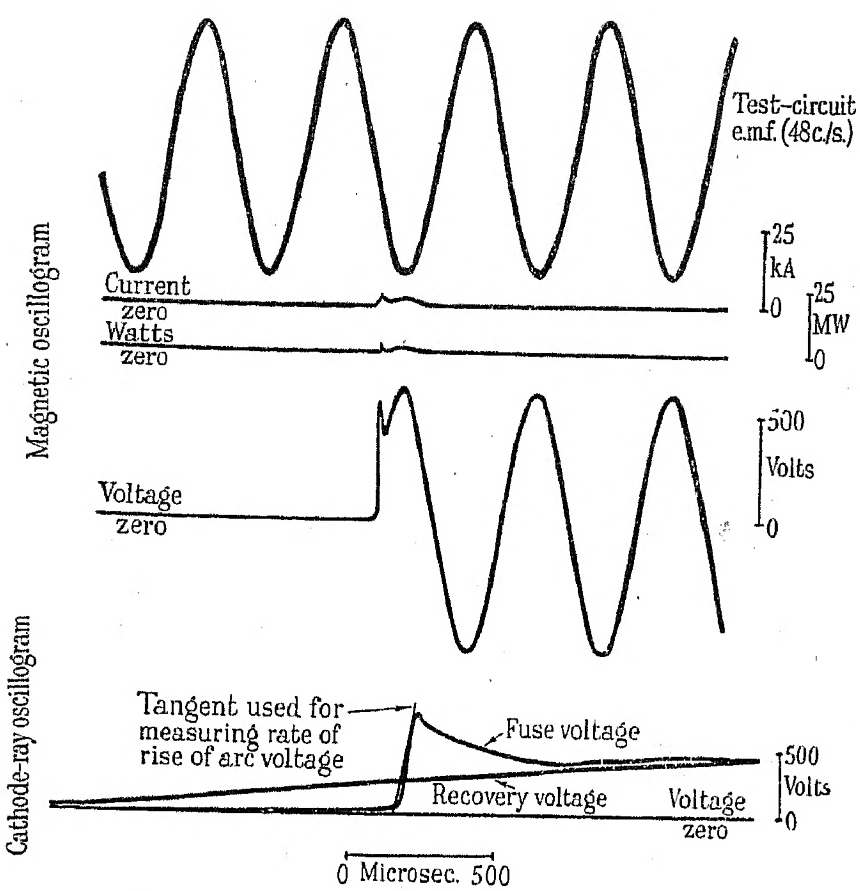

Fig. 2.—Category 440AC4 test on 60-amp. fuse, in circuit of high natural frequency.

No condenser across fuse.
Measured natural frequency = 238 kc./s.
Natural recovery rate of circuit, taken tangentially, at initiation of arcing = 265 V/μsec. (maximum rate is 1·15 times greater).
Actual rate of rise of arc voltage, measured tangentially from oscillogram = 11·2 V/μsec.

designer to guard against this trouble, which is more prevalent in d.c. than in a.c. circuits and appears to be caused by erratic behaviour of the arc at low currents.

The breaking capacity of a fuse is roughly dependent on the limiting value of arc energy which it can absorb from the circuit; the relation between arc energy and the circuit constants is therefore important. The fuse must obviously be able to absorb at least the inductive energy stored in the circuit. In practice the arc energy exceeds the inductive energy in a ratio, called the "arc energy ratio," which varies from approximately unity up to perhaps 6 or 7. The ratio alters little with changes in inductance, but depends on resistance and, more particularly, on the circuit voltage. The lower the arc voltage in relation to the circuit voltage, the higher is the ratio, or, in other words, the greater is the "follow-through" energy which the fuse must absorb.

It can be shown that for a fuse having considerable current-restricting effect, the inductance energy stored in the circuit varies only as the cube root of the inductance. Such a fuse is capable of dealing with widely varying values of circuit inductance and resistance. Increase in voltage, on the other hand, increases the severity considerably since the arc energy which the fuse has to absorb increases rapidly with voltage on account largely of the increase in arc-energy ratio.

In the case of short-circuit operation on alternating current, the severest condition arises when arcing commences a little before the peak of the supply voltage. Unlike circuit-breakers, the cartridge fuse frequently finds short-circuit operation on alternating current more difficult than on direct current at the same nominal voltage.

Choice of Materials

The metals principally used for fuse-elements are silver, copper, aluminium and zinc; silver, apart from its high cost, is on the whole the best. It is very free from oxidation and although its value of Preece's coefficient is rather lower than that of copper, necessitating a somewhat greater section for a given current, this factor is more than outweighed as regards breaking capacity by the lower specific heat of silver, resulting in more pronounced current restriction. Its lower Preece's coefficient and its lower resistivity result in an ohmic loss which is less than for copper, and does not greatly exceed that for tin.

There are two general types of filler:—

(1) The inert filler which, in being fused by the arc, gives rise to only limited chemical action. The most usual material of this sort is silica.
(2) The filler which gives off gas when heated by the arc, the action being endothermic. The commonest example of this class of filler is calcium carbonate, the gas evolved being CO_2, which is believed to assist in arc extinction.

High mechanical strength is usually considered to be necessary in fuse bodies, which for this reason are commonly made of ceramic material of a grade having special resistance to heat and internal pressure.

Available Types of Fuses

Fuses for low and medium voltages can be divided into (*a*) those using elements of one metal only, and (*b*) those with composite elements. For the first, silver is almost always chosen because of its advantages already enumerated. Except for ratings below about 10–20 amp., subdivision of the elements is commonly employed. Most designs use necked elements to assist in cool running and to reduce voltage surges. A typical fuse-link with silver elements is shown in Fig. 3. The object of the composite-element construction is to afford longer time-lags than are associated with simple silver elements. The lag is dependent on the time for the heat generated at a neck or necks to travel along the elements to a mass of low-melting-point alloy which causes interruption either by itself fusing or, in another type, by amalgamation with the main part of the element.

Some designs of high-voltage fuse are similar to those in use at lower voltages, but with an appropriately increased length of body. In other instances the required length of element is obtained by winding it in the form of a helix on a ceramic core of star-shaped cross-section running along the axis of the fuse tube, the space between the two members containing the filler.

Applications

The principal uses of low- and medium-voltage H.R.C. cartridge fuses may be summarized as:—

(1) The sole line of protection on distribution boards in substations.
(2) In distribution networks.
(3) Service fuses in domestic and similar circuits.
(4) In general industrial distribution, both in main factory feeders and for backing up motor starters.

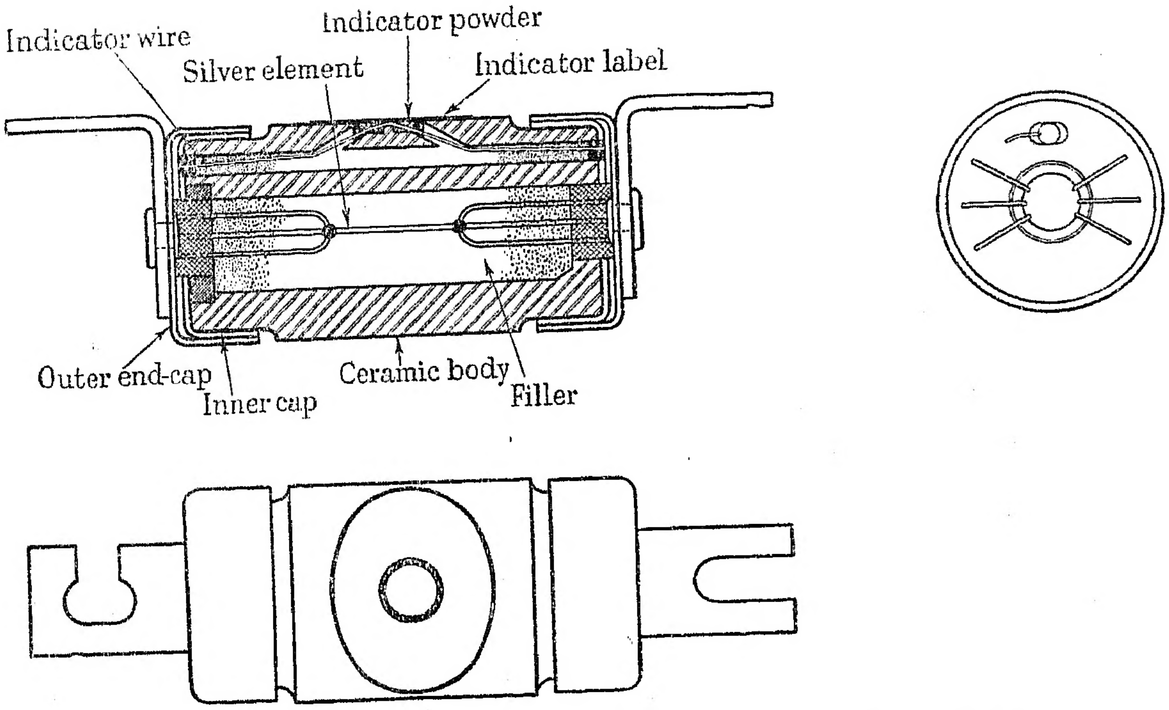

Fig. 3.—Typical silver-element fuse-link for low or medium voltage.

(5) For the backing-up of circuit-breakers of inadequate breaking capacity.
(6) For certain special application such as mercury-arc-rectifier anode circuits, traction work and the protection of power-factor-correction condensers.

Discrimination between H.R.C. cartridge fuses and other protective gear is important. For satisfactory discrimination between an H.R.C. sub-circuit fuse and an H.R.C. main fuse, the fusing-current/time curve for the former must lie below the corresponding curve for the latter. Discrimination becomes less certain as the prospective current is increased, since the pre-arcing time decreases much more than the arcing time, and it may become necessary to increase the rating of the main fuse.

Cartridge-type service fuses are frequently employed in domestic installations and are required to operate only on the failure of a semi-enclosed sub-circuit fuse. Discrimination difficulties may here arise on account of the large cross-section of element in a semi-enclosed fuse; the I.E.E. Wiring Regulations recommend that in such a easc the current rating of the largest consumer's fuse shall not be greater than one-third of the current rating of the service fuse.

The limited breaking-capacity of motor starters leads to the use of back-up H.R.C. fuses to deal with electrical faults, leaving to the starters their proper duty of protecting the motor against overload. The resulting requirement that the fuses shall operate only above a certain current is met if the current/time curves of fuse and starter intersect at this critical current, which, for direct-started squirrel-cage motors, is approximately equal to the machine standstill current. It is, however, not entirely sufficient that the fuses shall relieve the starter of attempting to break short-circuits; its contacts and magnetic or thermal trips should also be protected as far as possible against the destructive mechanical and thermal effects of the current. The protection of this sort resulting from the current-restricting effect of the fuses is more satisfactory the lower their rating (compare Fig. 1).

Similar considerations of discrimination and current-restriction apply to the protection by H.R.C. fuses of circuit-breakers of inadequate breaking capacity.

THEORY AND EXPERIMENTAL CONFIRMATION OF CALIBRATION OF FIELD-STRENGTH MEASURING SETS BY RADIATION

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(Abstract *of a paper which is being published in March in Part III of the Journal.*)

The investigation here described is a continuation of that reported in an earlier paper by McPetrie and Pressey.† In that paper it was shown that a very convenient method for the calibration of short-wave field-strength measuring sets was possible using a small radiating source so arranged as to produce a horizontal electric field at the aerial of the receiver whose calibration is required. If the strength of such a radiating source is known, the field

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strength E at the receiver is readily computable from the equation

$$E = \frac{240\pi^2 h_T h_R}{\lambda^2 d^2} KF \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

h_T and h_R = transmitting and receiving aerial heights respectively,

λ = wavelength,

d = distance between transmitter and receiver,

K = metre-amperes of the transmitting aerial, and

F = a function of the electrical constants of the ground.

If the unit of length in Equation (1) is metres, the field-strength (E) is given in volts/metre. On wavelengths less than about 10 metres, and for values of the angle $4\pi h_T h_R/(\lambda d)$ less than about 20°, the magnitude of F is unity.

The simplicity of the radiation method using horizontally polarized electric waves for the calibration of short-wave field strength depends upon the fact that F is unity and independent of the type of ground over which the calibration is made. This radiation method, however, can be used on wavelengths greater than 10 metres where F is no longer unity, if the appropriate value of F is used to compute the field strength at the receiver. Curves giving the variation of the magnitude of F with wavelength for typical transmitter and receiver heights are included in the complete paper.

It has been shown recently that under conditions for which $4\pi h_T h_R/(\lambda d)$ is small the propagation characteristics of horizontally and vertically polarized waves are identical for wavelengths shorter than above 10 metres. As the wavelength is increased about this limit, however, the value of F in Equation (1) remains about unity for horizontally polarized waves, but increases rapidly for vertically polarized radiation.

The field strength in the vertical direction from a vertical aerial is much greater than the field strength in the horizontal direction from the same aerial when arranged horizontally. If, now, the radiating aerial used for calibration in the horizontally polarized radiation method has a small component which radiates a vertically polarized electric wave, the magnitude due to the latter at the receiving aerial may be much greater than the horizontal field due to the larger horizontal aerial component. Unless the nominally horizontal aerial is adjusted carefully so that it is not influenced by vertically polarized radiation an error in calibration of the receiver would ensue if it were assumed that the electromotive force in the receiving aerial was induced only by the horizontal component of the transmitting aerial. It is shown in the paper that this effect is such as to set an upper limit in wavelength of about 30 metres to the useful range of the radiation method involving horizontally polarized radiation.

In order to verify the conclusion that the radiation method can be used on longer wavelengths, a comparison was made of the radiation and a laboratory method for calibrating a field-strength measuring set. The wavelengths selected for comparison were 8 metres and 20 metres (frequencies of 37·5 and 15 Mc./s.), representing approximately the lower limit of the laboratory and the upper limit of the radiation method respectively. The sensitivities of the measuring set determined by the radiation method from Equation (1) were 4·8 μV/m. and 2·6 μV/m. at the wavelengths 8 metres and 20 metres respectively. The corresponding sensitivities found by the laboratory method described in the paper by Colebrook and Gordon-Smith (see Part III, No. 1, p. 15) were 5 μV/m. and 2·5 μV/m. The close agreement between the results obtained with the two methods indicates that either can be used in the waveband 8–20 metres. This by no means represents the complete range of the radiation method, which can be used on any wavelength below 8 metres and, probably, would still be convenient up to a wavelength of 30 metres.

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